
An Evaluation of MTC Specifications for Tree Planting and Maintenance Techniques

-- Interim Report



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Technical Report Documentation Page**An Evaluation of MTC Specifications for Tree Planting and Maintenance Techniques -- Interim Report**

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Number:	IR-77
Date of Publication:	December 1987
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Abstract:	There are conflicting reports in the literature regarding the best methods of transplanting trees into the road-side environment. Most of the studies reported, however, deal with climates and species not typical of Ontario. A study was therefore undertaken to provide definitive answers, and to validate or improve MTC specifications for tree planting along Ontario's roadsides. In early 1985, test plantings were made of ash and spruce, and a variety of treatments were applied. These fell into four major categories: • backfill, • pruning, • mulching/weed control, and • staking. This interim report describes the experimental design and reports the results obtained in the 1985 growing season.
Comments:	See also report ME-87-07
Key words:	horticulture, trees, planting specifications, transplanting, roadside environment
Distribution:	Environmental and municipal works engineers, MTC districts and regions, maintenance engineers
Copyright Status:	Crown copyright

An Evaluation of MTC Specifications for Tree Planting and Maintenance Techniques

-- Interim Report

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Published by
The Research and Development Branch
Ontario Ministry of Transportation
Hon. Ed Fulton, Minister
D.G. Hobbs, Deputy Minister

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December 1987

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1/ INTRODUCTION

Trees are desirable components of the roadside environment. They help to reduce wind, erosion, snow drifting, and salt spray damage to adjacent properties, and they add visual variety to reduce driver fatigue. One million dollars are spent annually by the Ministry to establish new plantings of trees and shrubs along the roadsides of Ontario.

While trees and shrubs are naturally slow growing during the first one or two years after transplanting, many roadside plantings have exhibited reduced growth long after the initial establishment period.

There has been much debate within the landscape industry as to the best method of transplanting woody plants. Traditionally, planting specifications have called for a high percentage of organic material in the backfill, and often the backfill material is composed entirely of material foreign to the planting site. In addition, quantities of fertilizer are also added to the backfill. Most specifications also call for pruning the tree at planting to compensate for root loss during digging, mulching the planting area, and rigidly staking the tree.

Recently published research results questioning the validity of amended planting soils have fuelled the debate over this traditional horticultural practice. Numerous studies have revealed no growth differences between trees planted in amended or unamended soils (Corley, 1984a; Corley, 1984b; Feucht, 1979; Schulte and Whitcomb, 1975; Whitcomb et al, 1976). In some cases, the use of soil amendments was found to be detrimental to tree growth after transplanting (Schulte and Whitcomb, 1975; Townsend, 1973; Wagar, 1982; Whitcomb, 1979).

In contrast to these results, there have also been positive plant responses to soil amendments. Amending the backfill soil with sand reduced both the shoot:root ratio and xylem water potential in holly (Randolph and Wiest, 1981). A thorough study of various amendments on both clay loam and loamy coarse sand soils found that replacement of the site soil with a loam soil maximized growth after transplanting (Pellet, 1971). Roots have been observed to proliferate in amended soils as a result of the optimal conditions present for growth (Barnett et al, 1983; Feucht, 1979; Schulte and Whitcomb, 1975; Whitcomb, 1979). In the long

term, root growth may be confined to the planting hole and, as the canopy of the tree increases in size, the ability of the confined root system to provide support and supply the canopy with water and nutrients will decline (Whitcomb, 1979).

Conflicting results have also been reported as to the effect of pruning on survival and growth after transplanting. Most results indicate that pruning stimulates shoot elongation and tree vigour (Castle, 1983; Oskamp, 1930). However, where root response was also measured, the stimulation of shoot growth by pruning is accompanied by an inhibition of root growth (Fordham, 1972; Head, 1967; Kandiah et al, 1984; Kelly and Moser, 1983; Knight, 1934; Randolph and Wiest, 1981; Wrigley and Smith, 1978; Young and Werner, 1982; Young and Werner, 1984). Traditional transplanting practices dictate that trees should be pruned at transplanting to "balance" the top and root or to reduce the quantity of top growth that must be supported by a reduced root system (Anon., 1963; Anon., 1977; Flemer, 1982; Himelick, 1981; Thompson, 1954). The actual experimental results previously cited indicate that pruning may actually inhibit tree establishment by stimulating shoot growth at the expense of root growth.

A layer of mulch material is commonly placed on the soil surface around transplanted trees. This practice is supported by extensive research that shows clearly the benefits of mulching (Fraedrich and Ham, 1982; Litzow and Pellett, 1983; Whitcomb, 1979; Whitcomb, 1980; White and Holloway, 1967). Mulched trees had a higher rate of survival and greater height, shoot, and diameter growth (Buller and Gibbs, 1952; Fraedrich and Ham, 1982; Litzow and Pellett, 1983; Whitcomb, 1979). The use of mulches also increases the quantity of root growth (Coker, 1958; Fraedrich and Ham, 1982; Whitcomb, 1980; White and Holloway, 1967). Root growth under mulches often occurs at the soil/mulch interface or directly into the mulch material (Coker, 1958; Fraedrich and Ham, 1982). This would be detrimental if the mulch were removed at a later date or if the temperature or moisture conditions within the mulch were subject to extreme variations.

Mulching reduces soil moisture loss, moderates temperature fluctuations in the soil, reduces competition from weeds and, in the case of organic mulches, can contribute to the fertility and structure of the soil.

Numerous mulching materials are used, the majority of which are organic (wood chips, straw, peat, corncobs, pine needles, compost, bark, grass clippings, leaves, and other organic refuse), although some inorganic materials are used (plastics, geotextile fabric, stone, sand, and a variety of inorganic waste materials). Each material possesses different characteristics when used as a mulch.

As an alternative to mulch, herbicides have been used to prevent vegetation from competing for water and nutrients with recently transplanted trees (Atkinson, 1977; Barber, 1984; Nielson and Wakefield, 1978; Shipman, 1974; White and Holloway, 1967). Under herbicide treatment, roots proliferate in the area where grass is removed by the herbicide, presumably in response to reduced competition (Atkinson, 1977). Herbicide treatments compared favourably with the use of organic mulches, although in some cases organic mulches were found to be superior. The main advantage of using herbicides over mulching is the much lower cost of herbicide application.

Transplanted trees are traditionally staked rigidly to prevent wind knock-down, root damage from wind shifting, and to encourage straight trunk development. Early researchers discovered the importance of wind-induced tree motion in the development of a solid trunk (Jacobs, 1954). More recent research indicates that rigidly staked trees may develop less trunk taper and a reduced ability to remain upright after the stake is removed (Harris, 1984; Harris and Hamilton, 1969; Leiser et al, 1972; Wrigley and Smith, 1978). These studies question the need for rigid staking and recommend more flexible staking (Harris, 1984), and a lower height of staking (Leiser and Kemper, 1968), to aid the development of a structurally sound trunk while still preventing the tree from being blown over by the wind.

The preceding overview of the literature illustrates the controversy that exists with regard to transplanting landscape trees. Many of the studies cited have been performed with different species and under different environmental conditions than those commonly found in Ontario. The University of Guelph was approached by MTC to design and execute a study of roadside planting and maintenance techniques that would be valid for the Ontario roadside environment. The objective of this study is to

determine the validity of specific tree planting practices and procedures currently required by MTC specifications and, if warranted, to recommend alterations to the current specifications based upon the results of the study.

2/ METHODOLOGY

2.1/ Experimental Design

The two species selected for use in this study were green ash (*Fraxinus pennsylvanica lanceolata*), as the deciduous species, and Colorado spruce (*Picea pungens*), as the coniferous species. The ash were selected for uniformity in the field from the Ministry of Natural Resources Midhurst nursery. The spruce were acquired by a separate purchase order from a private nursery in southwestern Ontario. The trees were selected for uniformity after they had been dug. All of the trees were shipped to, and stored at, MTC Stratford District yard until planting.

The specific treatments are:

1/ backfill

- a) topsoil and peat -- as currently in specs
- b) unamended site soil
- c) equal parts of (a) and (b)

2/ pruning

- a) none (Fig. 1)
- b) "to compensate for root loss" -- as currently in specs
one-third of all lateral growth was removed (Fig. 2)

3/ mulching / weed control (Fig. 3)

- a) 100 mm of wood chips -- as currently in specs
- b) herbicide weed-free ring
- c) no surface treatment

4/ staking (Fig. 4)

- a) approx. 75 cm height, 1-year duration
- b) approx. 75 cm height, 3-year duration
- c) approx. 150 cm height, 1-year duration
- d) approx. 150 cm height, 3-year duration
- e) none

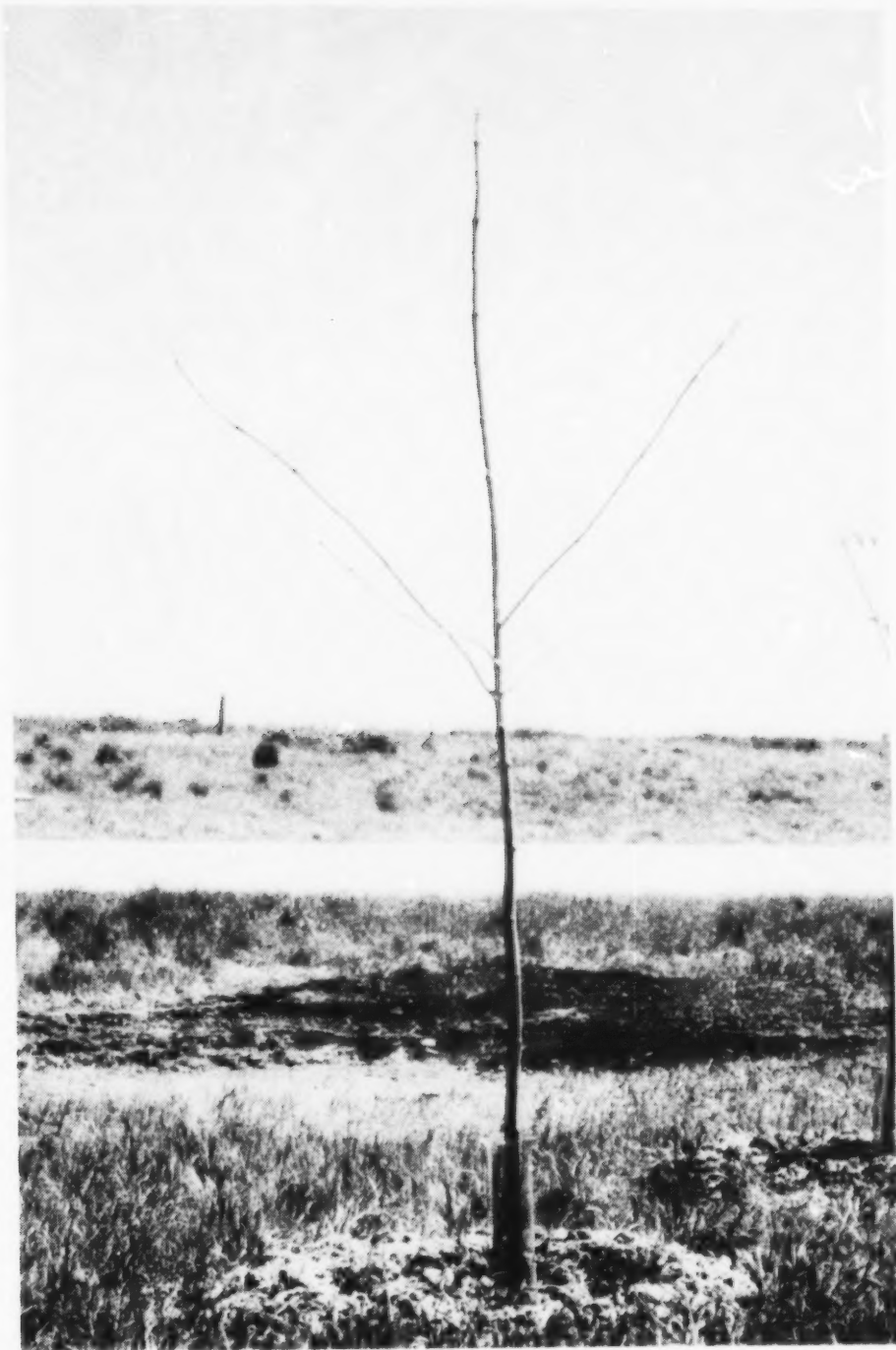


Figure 1/ Ash tree prior to pruning treatment

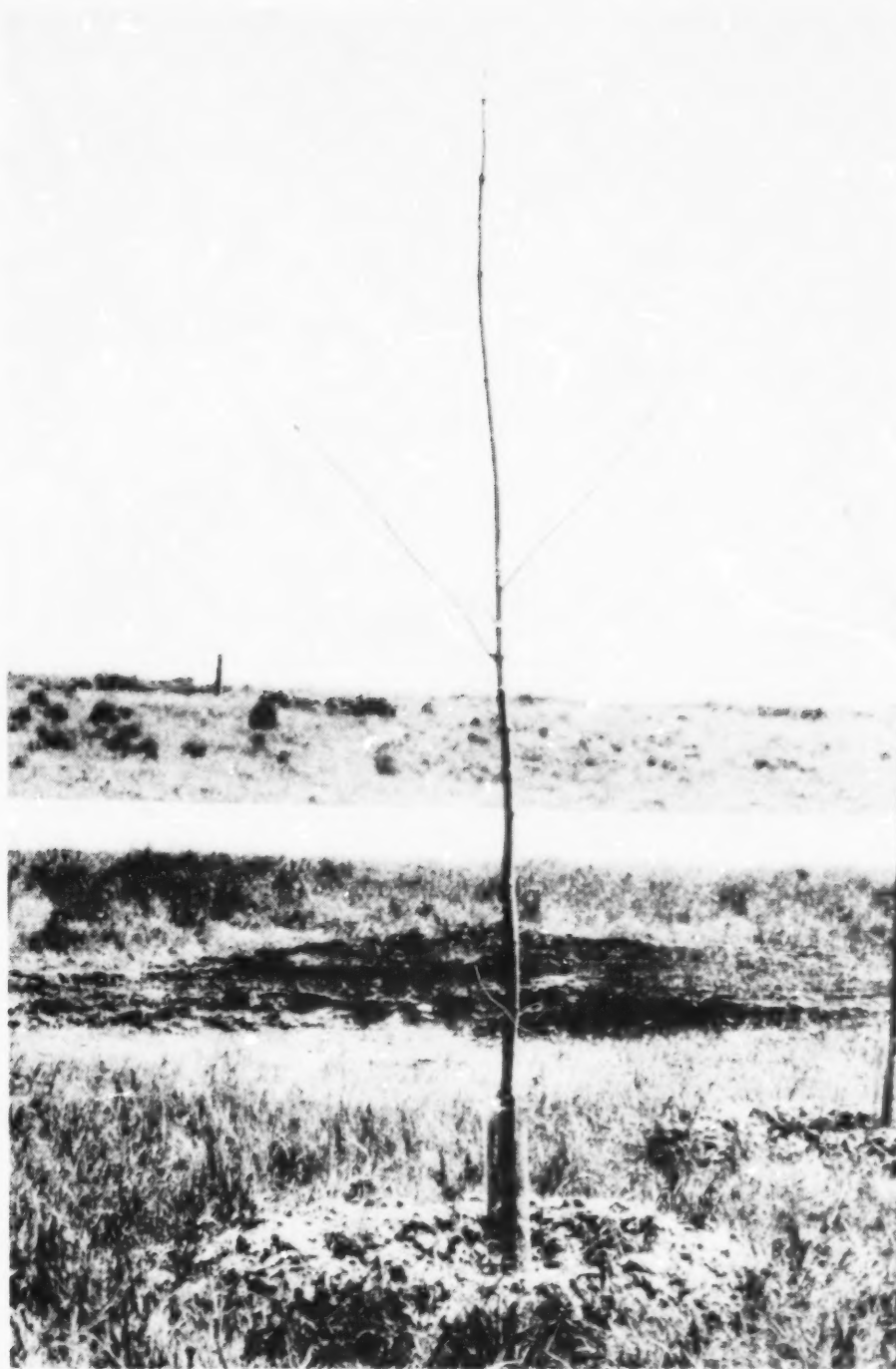


Figure 2/ Ash tree after pruning treatment

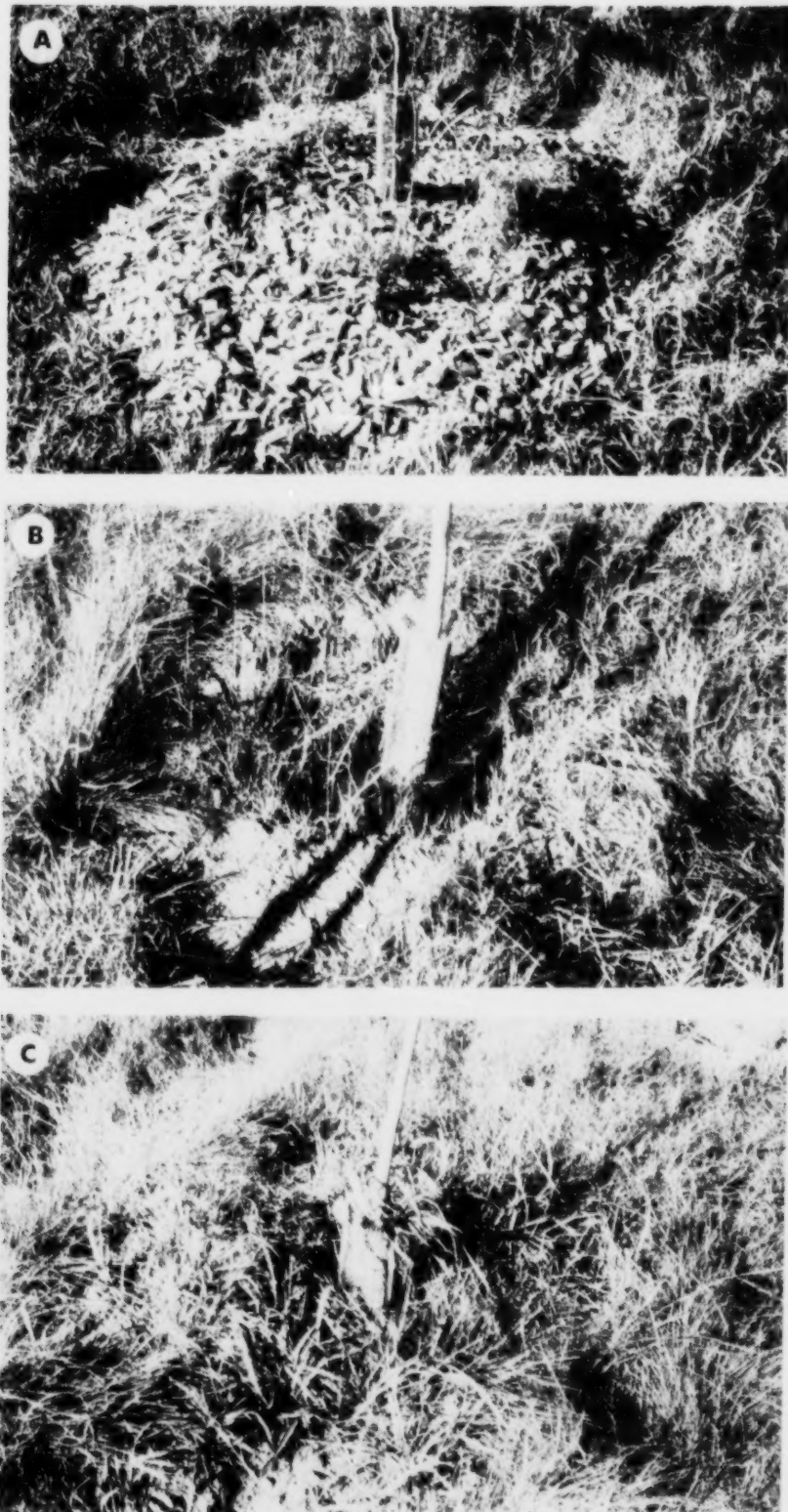


Figure 3/ Ash trees with:
a) wood chip mulch,
b) herbicide weed-free ring, and
c) no surface treatment.

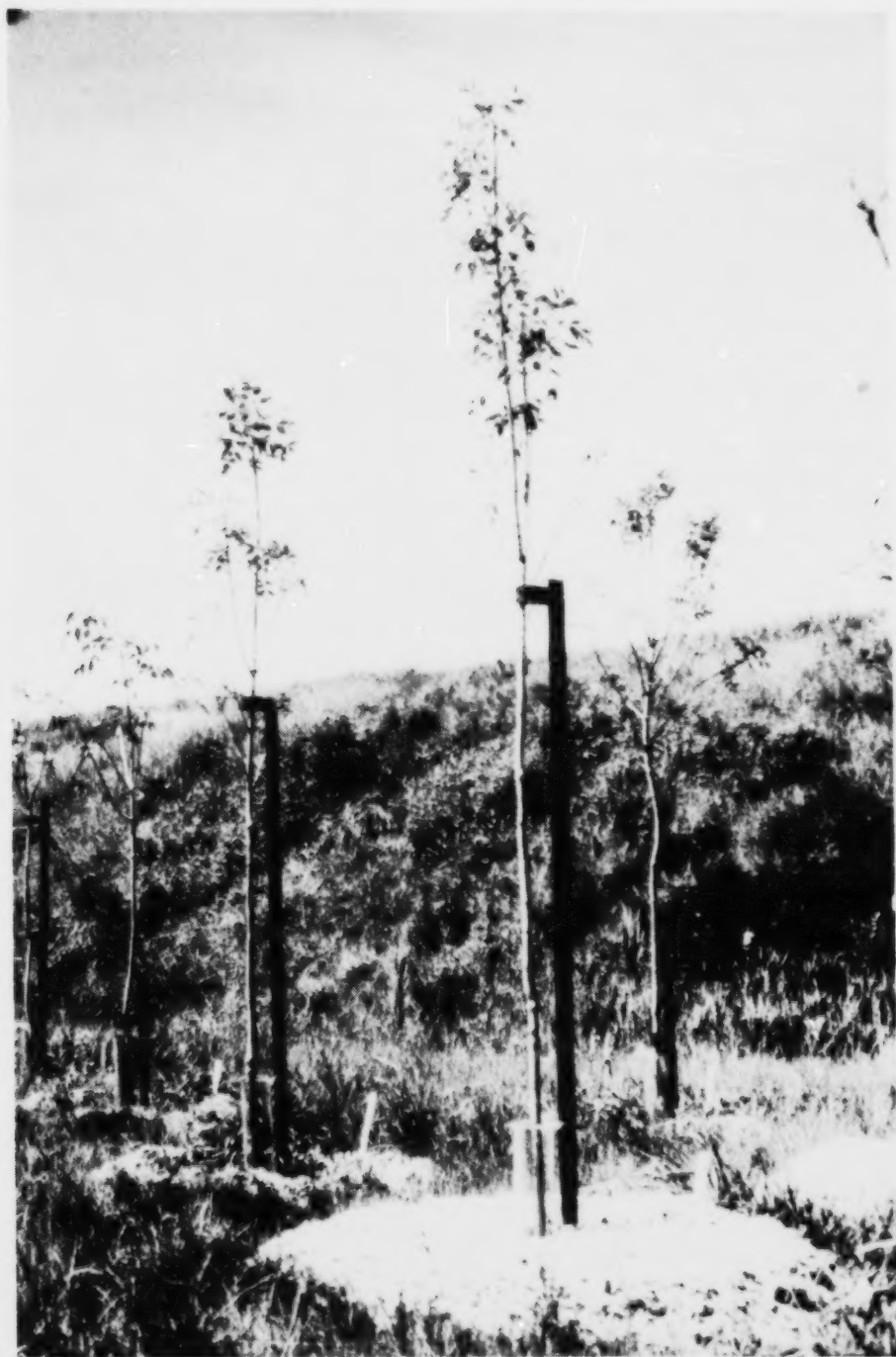


Figure 4/ Staking treatments of ash trees. The 150 cm height of attachment is in the foreground and the 75 cm height of attachment is in the background.

All of the treatments were applied to both species, with the exception of pruning and staking on the spruce. The ash experiment is a rectangular lattice design in a factorial arrangement with three replications (blocks) of the basic design. This design allows each treatment effect to be isolated individually and also allows pooling of results if a particular treatment or treatments prove to have no effect. The total number of ash trees in the experiment is 270 with 90 trees per replicate (block). The spruce portion of the study is a basic randomized complete block design in a factorial arrangement with three backfill treatments and three mulch treatments. There are 15 replicates (blocks) of the basic design for a total of 135 trees.

2.2/ Site Selection

In order to maximize the value of this study to the Ministry, it was decided that the major experiment would be carried out on a "typical" roadside site. Several possible sites were submitted by MTC staff.

The site finally selected is located just south of Regional Road 17 on the west side of Highway 86 near the village of St. Jacobs (Fig. 5). The site was quite uniform, easily accessible, and had sufficient area to adequately house the experiment. One problem with the site is an excess of topsoil overlying the heavy clay subsoil. This problem was effectively dealt with by separating the clay from the topsoil at the time of planting to provide a pure clay backfill treatment. In addition, the site had some very wet, poorly drained areas. These areas were easily distinguishable in early spring and the experimental plot was designed to exclude these areas.



Figure 5/ View of planted site along Hwy 86 south of Regional Road 17

2.3/ Planting

The site was laid out and the holes were augered in late April. The trees were planted with the assistance of the MTC Stratford District landscape crew during the first two weeks of May. All of the ash trees were planted during the first three days of May. A heavy rainfall delayed planting of the spruce until May 13 and 14. The amount of clay available from around the augered holes was insufficient to meet the needs of the native-soil backfill treatment. To supplement the clay collected from around the holes, additional clay was excavated from an area just south of the experiment site. All of the trees were watered by MTC with their water-fertilizer solution immediately after planting. The trees were watered again August 8 and 9. Watering requirements were low due to the high rates of precipitation during the 1985 growing season.

The staking treatments were applied shortly after all of the trees were planted. Ash trees were pruned, as previously described, during the period of May 24 to 28. A hardwood chip mulch was applied to one-third of the trees on June 10. The herbicide treatment was not applied until July 30 as there was insufficient weed growth in the backfill to justify its application prior to that date.

2.4/ Plant Measurements

Several plant characteristics were quantified as follows:

1/ Shoot Elongation

- a) ash -- Five swelling buds were selected at a midpoint in the canopy of each tree. Shoots arising from these buds were measured approximately once a month. In addition, the number of buds out of the original five that aborted was recorded. Shoot elongation was corrected for the remaining number of shoots, measured by dividing the total shoot elongation by the number of shoots measured.
- b) spruce -- At approximately bimonthly intervals through the growing season, ten shoots were randomly selected at the periphery of the plant canopy and measured.

- 2/ Height Growth was measured on the ash once at the end of the season. Height growth was defined as the amount of growth of the terminal shoot over the season. Height growth of the spruce could not be determined due to the high percentage of terminal buds that were damaged during transport of the trees.
- 3/ Trunk Diameter measurements were taken at regular intervals only on the ash. Two points on the trunk at approximately 80 cm and 160 cm from the soil surface, just above each of the two staking heights, were marked with red paint. The diameter at each of these heights was measured using Vernier calipers. Taper was calculated by the following formula:
- $$\text{Taper} = \frac{\text{Diameter (at 80 cm)} - \text{Diameter (at 160 cm) (mm)}}{\text{Height Difference of Measurements (800 mm)}} \times 1000$$
- The change in taper was the difference between the taper at the first measuring date and that at the final measuring date.
- 4/ Leaf Water Potential Measurements were made on two occasions on both ash and spruce. Individual ash leaves (three per tree) were excised at the base of the petiole with a razor blade. They were immediately inserted and sealed in the pressure bomb chamber with 2 cm of petiole extending from the chamber. The pressure was slowly increased until an exudate could be seen, with the aid of a magnifying glass, on the cut surface of the petiole. The amount of pressure required to produce an exudate is directly related to the leaf's water potential. A similar method was used on the spruce except whole new shoots were excised with a razor blade instead of individual needles which were too small to fit in the pressure chamber.
- 5/ Canopy Density of the ash was visually rated near the end of the growing season. Visual ratings of the spruce were made on August 6. The ratings were a subjective assessment of canopy density and tree health on a scale of 0 to 5 (0 = dead, 5 = best).

6/ Defoliate Date was recorded for each of the ash trees on a weekly basis in the fall.

7/ General Observations were made throughout the season on both species as well as site characteristics.

2.5/ Physical Measurements

1/ Soil Analysis

Soil samples of each of the clay, the native topsoil, and the imported amended backfill were collected for laboratory textural analysis and determination of organic matter content. Attempts to measure soil water content and the permeability of the different soils at the site were foiled by the extremely high moisture conditions present during the summer of 1985.

2/ Weather Data

Weather data collected at Environment Canada's Waterloo-Wellington Airport Station were acquired to represent the environmental conditions over the first growing season of the experiment. Soil temperatures were recorded for the different mulch/weed control treatments at the soil or mulch surface and 15 cm below the soil surface after all of the treatments had been applied.

2.6/ Container Experiment

An additional 20 trees of each species were transported to Guelph for use in a container study. There were two treatments in this experiment:

- 1) planted in the native clay soil, and
- 2) planted in the imported amended backfill soil.

The trees were planted in large plastic containers (50 gal) and grown at Guelph's container research facility. One-half of the trees in this experiment were harvested in the fall of 1985. The soil was washed from the roots and new root and shoot growth was recorded. It was difficult to distinguish new from old root growth in the spruce, so the amount of fibrous root present was used as an indicator of new root growth. The remainder of the trees will be harvested in the fall of 1986.

3/ RESULTS AND DISCUSSION

3.1/ Plant Measurements

3.1.1/ Shoot Elongation

a) Ash

The initial expansion and elongation of new shoots is dependent mainly upon the carbohydrate reserves produced the previous year. Thus the initial shoot growth potential would be approximately equal for each tree. However, after initial expansion and elongation have occurred, subsequent elongation is dependent upon the environmental conditions of the current season.

Shoot elongation in this study was measured by selecting five expanding buds and measuring the elongation of the five shoots that developed. In many cases, a number of the swelling buds aborted growth early in the summer. Closer examination of the selected buds that developed into elongating shoots revealed that trees planted in the amended backfill had a greater number of buds that successfully developed into new shoots (Fig. 6). The effect of this treatment was evident very early in the growing season.

The rate of shoot elongation was greater in the group of trees planted in the mixed backfill treatment than the unamended backfill treatment (Fig. 7), but there were no significant differences between the amended and unamended backfill treatments -- although there was a trend towards greater growth in the amended treatment. Apparently, shoot initiation and development was influenced by the backfill treatment, possibly as a result of more favourable moisture conditions in the amended and mixed backfills. Measurements of leaf water potential indicate that internal water stress was less in the trees planted in the amended backfill during the critical early period of shoot elongation. The measurements of shoot elongation were highly variable from tree to tree within each treatment.

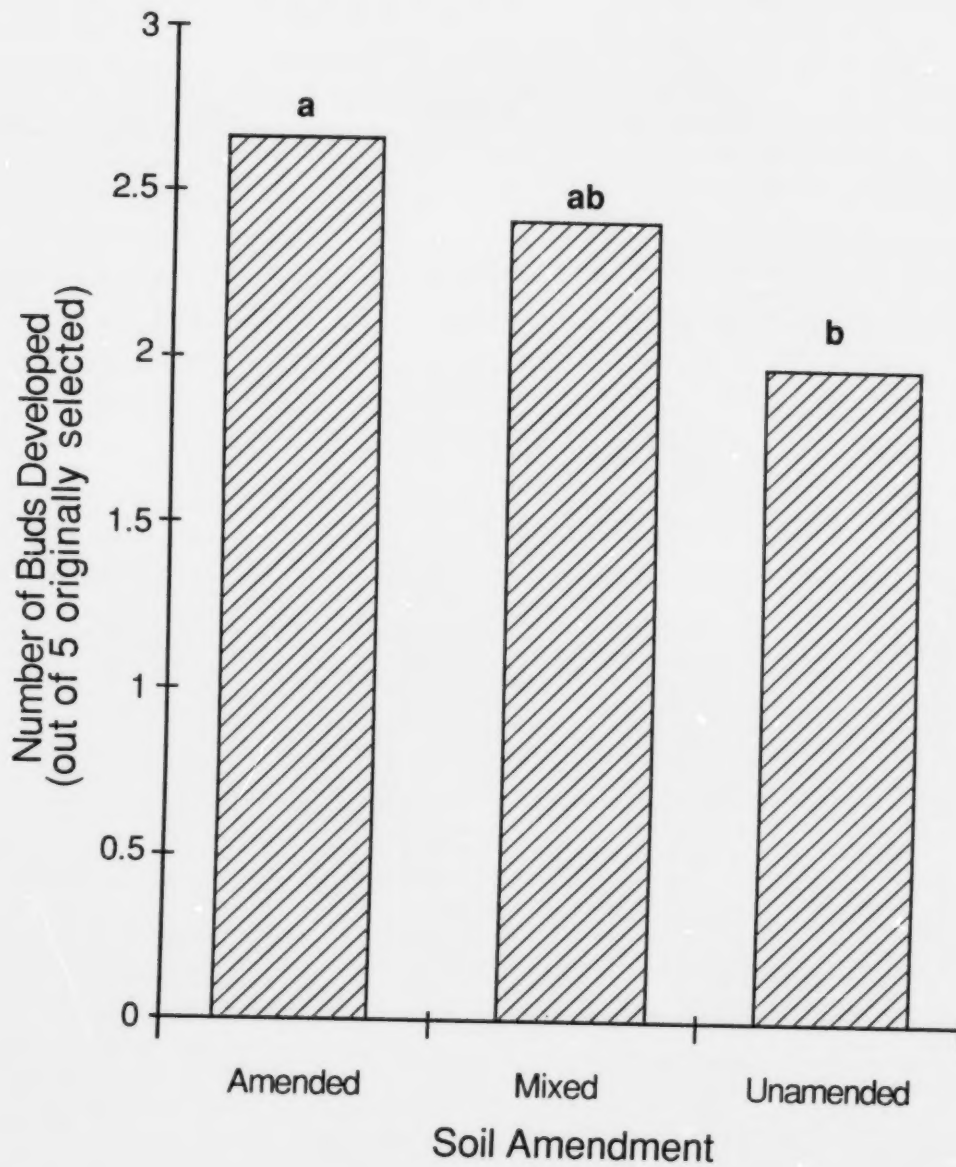


Figure 6/ The number of ash buds that developed out of five buds originally selected as influenced by backfill treatment. Bars with different letters above are significantly different at the 5% level using the LSD test.

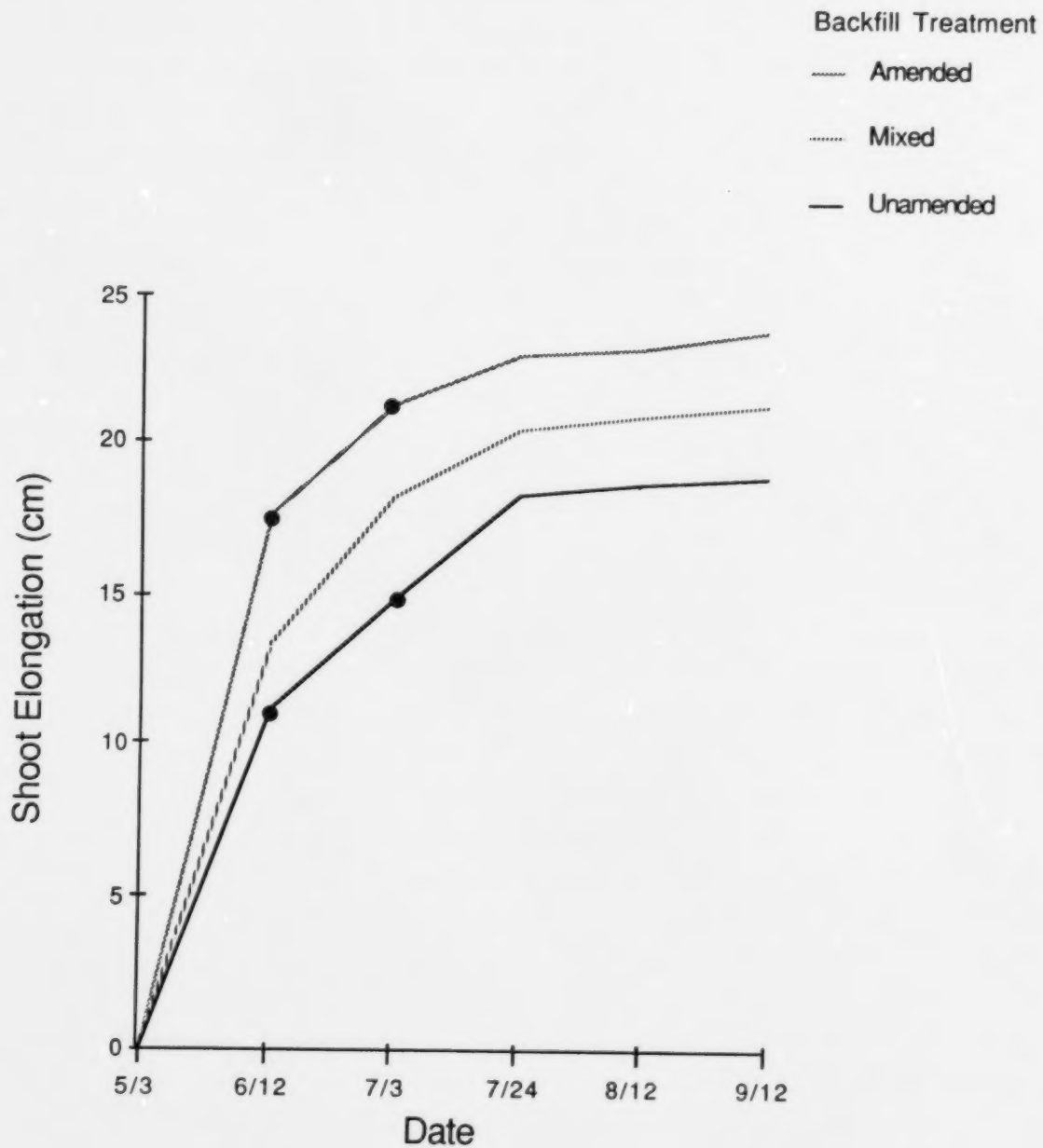


Figure 7/ Shoot elongation of ash trees as affected by backfill treatment. Points at the same date marked with a (•) are significantly different at the 5% level using the LSD test.

Trees that were pruned had a greater amount of shoot growth after the first measuring date (Fig. 8), although the results are not statistically significant. This trend of greater shoot elongation on pruned trees is most likely related to a reduction in the number of growing shoots by the pruning treatment and a resulting increase in the proportion of carbohydrate distributed to the remaining shoots.

b) Spruce

There was no difference among either the backfill or mulch treatments in the amount of shoot elongation in the spruce trees so shoot growth was averaged over all of the treatments (Fig. 9). Spruce, and conifers in general, have preformed shoots and initial elongation is primarily dependent upon carbohydrate accumulation the previous year. Shoot elongation would not be significantly reduced unless severe environmental conditions were encountered. Since the spruce trees in this study were planted with an intact soil ball, the initial effect of mulch or backfill treatment would be minimal. The intact soil ball and undisturbed roots within could support the water requirements of the tree, provided sufficient soil moisture was available. If soil balls were disturbed by the planting process, the trees would probably have reduced shoot elongation. The effect of the backfill treatments on shoot growth would only be observed after the roots have developed into the backfill soil or if the presence of the backfill soil adversely affected the soil moisture conditions within the soil ball.

3.1.2/ Height Growth

The quantity of height growth produced during the growing season was measured on the ash. There were significantly greater height increases in trees planted in the amended backfill (Fig. 10). The mixed backfill that combined the native clay with the amended soil had less height growth, followed by the native clay backfill which had the least growth of the three backfill treatments. The greater quantity of growth in the amended backfill is possibly related to the soil moisture conditions since available soil moisture is one of the main factors limiting shoot elongation in transplanted trees. There may have been greater aeration

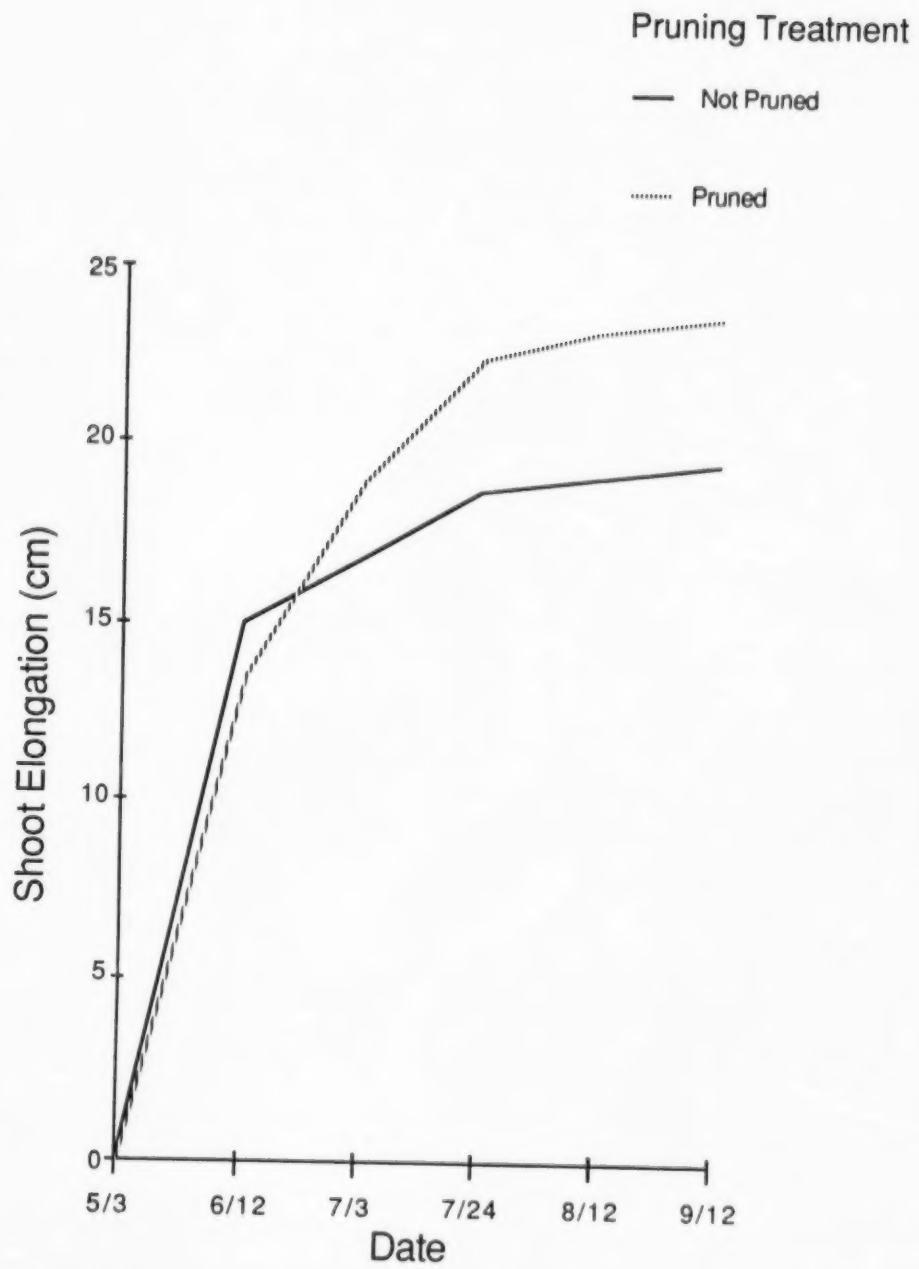


Figure 8/ Shoot elongation of ash trees as influenced by pruning treatment. Differences are not statistically significant

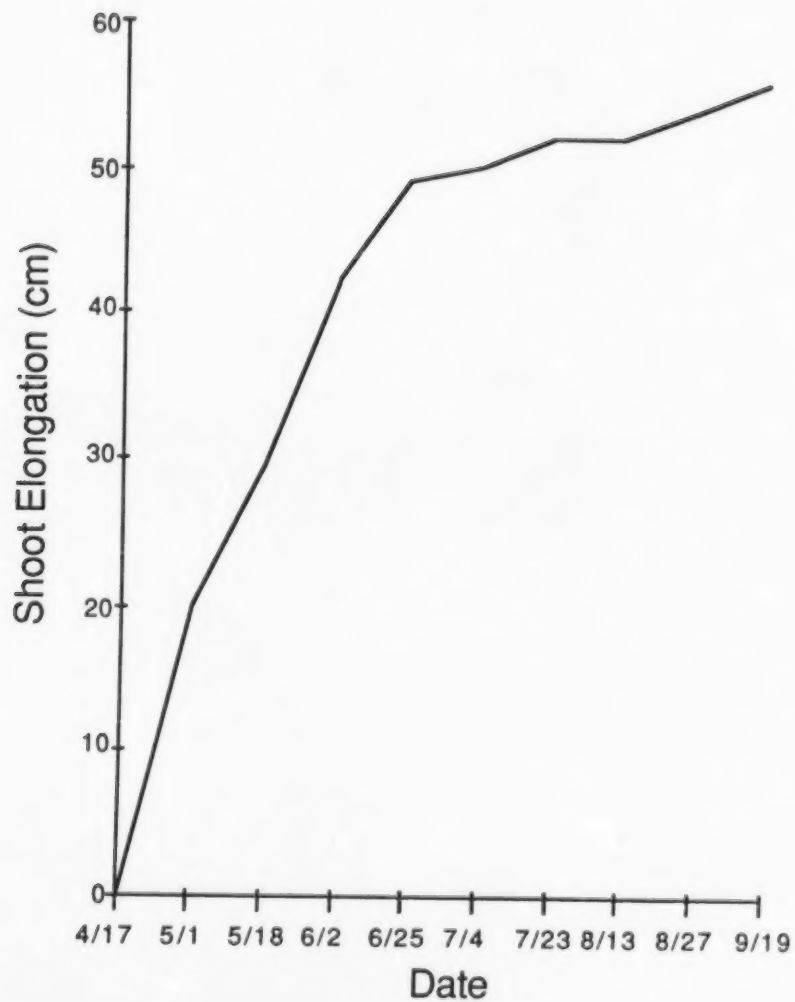


Figure 9/ Shoot elongation of spruce during the 1985 growing season averaged over all treatments.

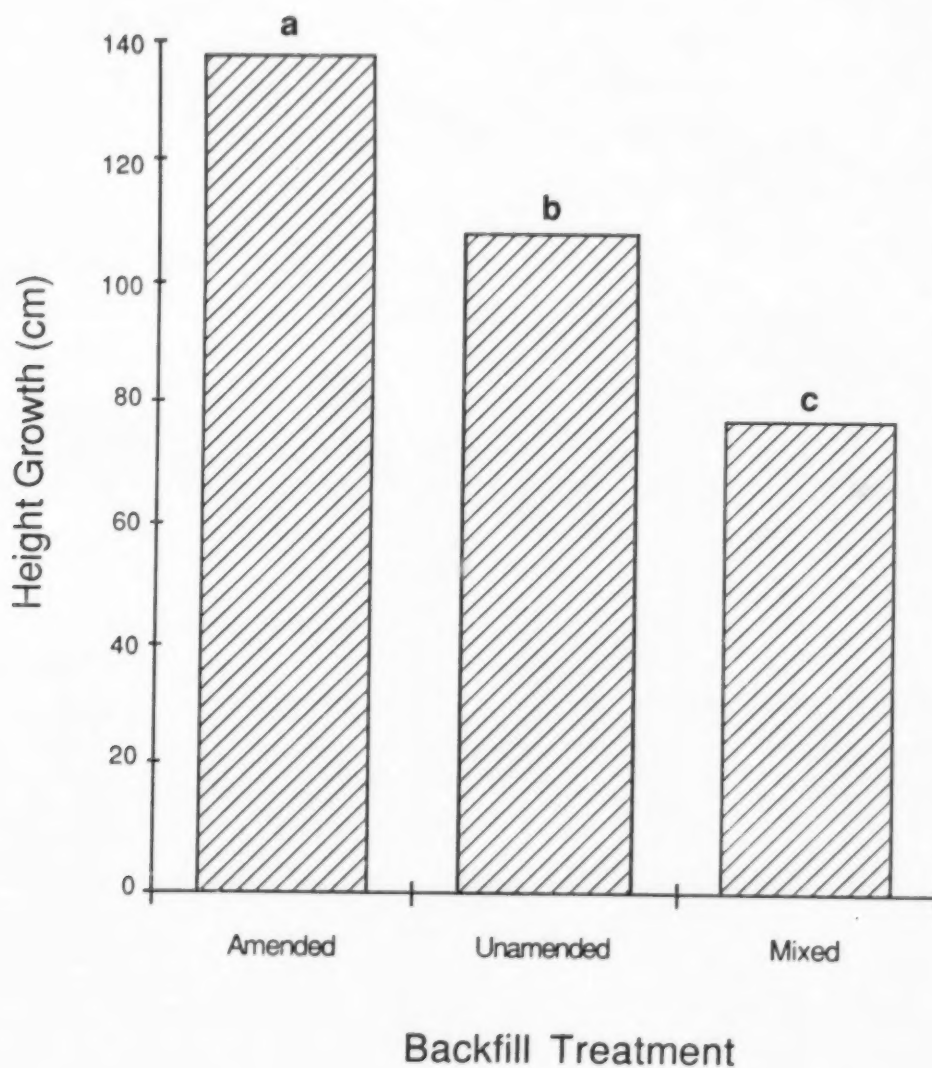


Figure 10/ Total height growth of ash trees as influenced by the backfill treatment. Bars with different letters above are significantly different at the 5% level using the LSD test.

in the amended mix, an important factor during what was a wet growing season. Leaf water potential measurements revealed that water stress was less in trees planted in the amended backfill (Fig. 15).

The quantity of height growth was greater in pruned trees than in unpruned trees (Fig. 11). Pruning stimulates the elongation of the remaining shoots, including the terminal shoot. Apical dominance may also be a factor as pruning removes lateral apices and thus reduces competition for water and nutrients within the tree.

3.1.3/ Trunk Diameter

Taper is important to the physical structure of the tree trunk and its ability to hold the canopy upright to effectively intercept solar radiation (Leiser and Kemper, 1973). A negative value of the change in taper indicates a reduction in taper. A positive value indicates normal taper development.

The block in which the trees were growing had a significant effect on the change in taper (Fig. 12). Block A, which was the closest block to the prevailing wind, had a net increase in the amount of taper. Blocks B and C which were farther downwind, and perhaps somewhat more sheltered from the wind, had decreasing values for the change in taper. This wind effect is purely speculative as no data was collected with respect to wind velocity within the blocks. However, since there was no block effect on any of the other parameters measured, wind movement of the trees appears to be the only plausible explanation for the observed block effect. It has been documented that wind movement of trees is a natural stimulus for the development of trunk taper (Jacobs, 1954; Neel and Harris, 1971). As a result of this block effect, the influence of the experimental treatments were studied within each individual block.

In blocks A and B, trees that were pruned had significantly less taper development (Fig. 13). The results agree with previous work studying the effect of pruning on trunk development of landscape trees (Harris and Hamilton, 1969; Leiser et al, 1972). Pruning reduces the development of taper possibly by changing distribution patterns of carbohydrate and growth regulators.

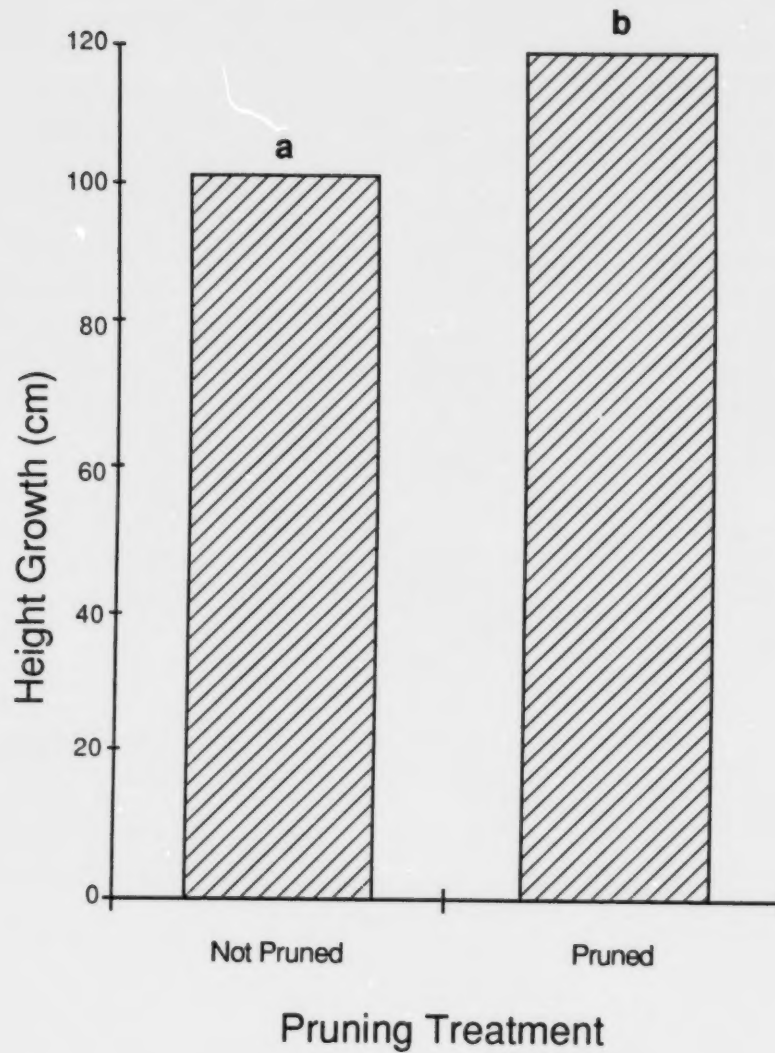


Figure 11/ Total height growth of ash trees as influenced by pruning treatment. Bars with different letters above are significantly different at the 5% level using the LSD test.

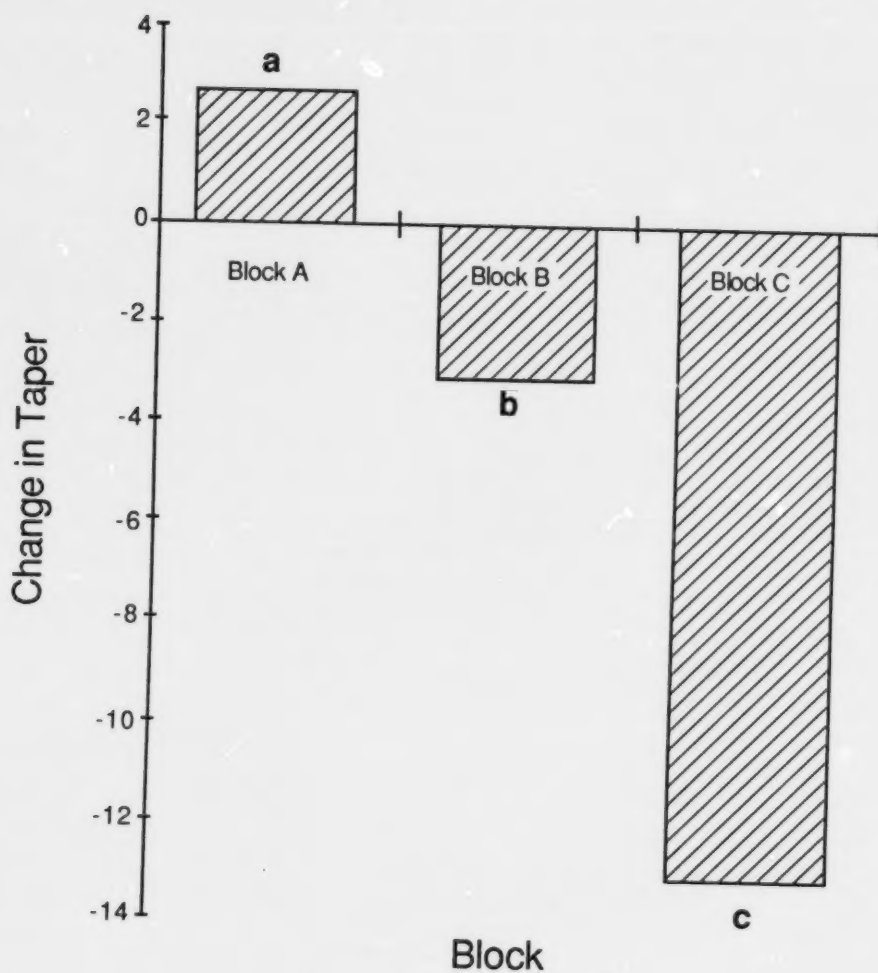


Figure 12/ Change in taper of ash tree trunks as influenced by location of block. Bars with different letters above are significantly different at the 5% level using the LSD test.

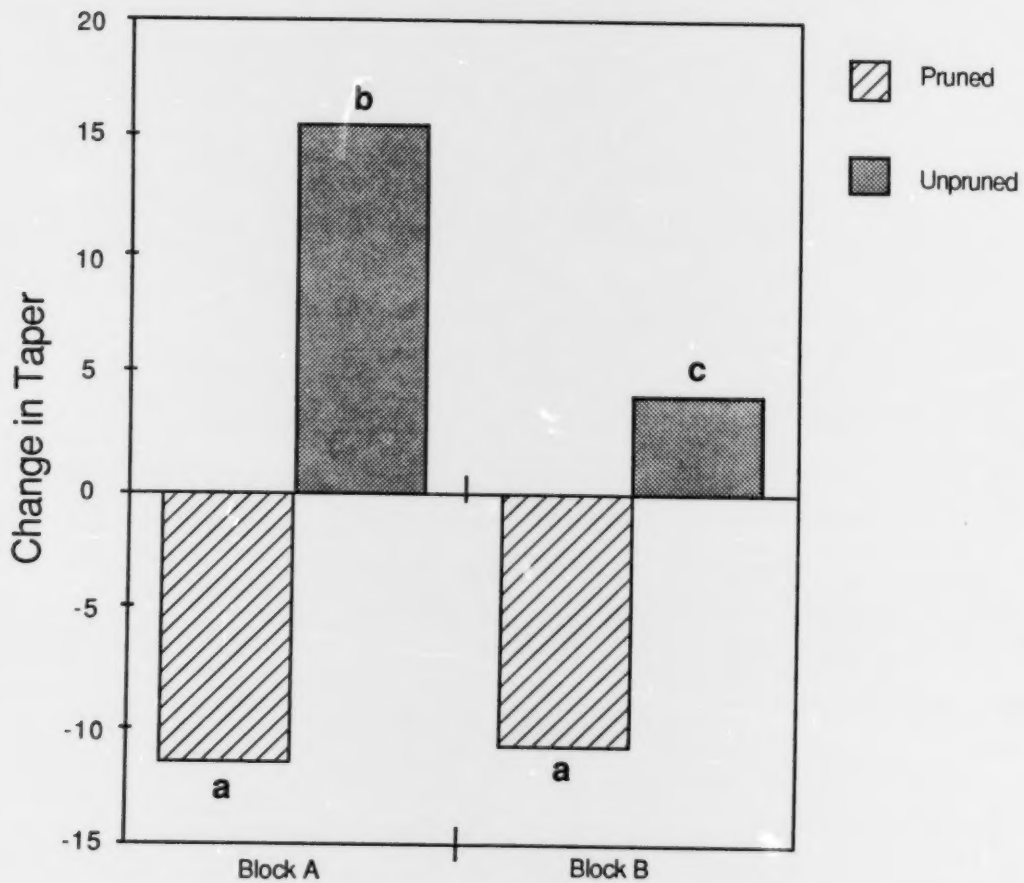


Figure 13/ Change in taper of ash tree trunks as affected by pruning treatment. Block C had no pruning treatment effect. Bars with different letters above are significantly different at the 5% level using the LSD test.

Taper development was also influenced by the presence and height of rigid staking (Fig. 14). Unstaked trees had the greatest amount of taper development. Trees staked at a height of 150 cm had a reduction in taper as compared to the unstaked trees in all three blocks. Previous research has found rigid staking to be detrimental to the natural development of trunk taper (Harris, 1984; Leiser et al, 1972). Trees staked at the lower height (75 cm) did not have as great a reduction in taper. Lower staking increases the length of trunk that can bend in the wind, an important consideration in the development of a physically sound trunk. While unstaked trees had the best taper development, several trees were blown over by the wind resulting in an undesirable tree form.

3.1.4/ Leaf Water Potential

a) Ash

Leaf water potential was measured at two dates during the growing season (Fig. 15). The measurements on each block required a full day to perform. As environmental conditions can significantly influence the values recorded, each block must be considered individually.

Water potential values were lower for trees planted in the amended backfill than either the mixed or unamended treatments in blocks A and B (Fig. 15) at the first measuring period (July 17, 23, and 24). The mixed backfill was somewhat intermediate in value between the amended and unamended treatments. At the second measuring period (August 23, 24, and 27), there was no difference between the three backfill treatments except for the measurements in block B.

It appears that, initially, trees planted in the unamended backfill had greater stress levels, as indicated by the more negative water potential values. At the second measuring period, there was no significant difference between the treatments. A similar pattern was observed in an experiment comparing sand amendment at planting (Randolph and Weist, 1981). Trees planted in a sand only backfill had more negative values at a July measuring date but by August there was very little difference between the treatments.

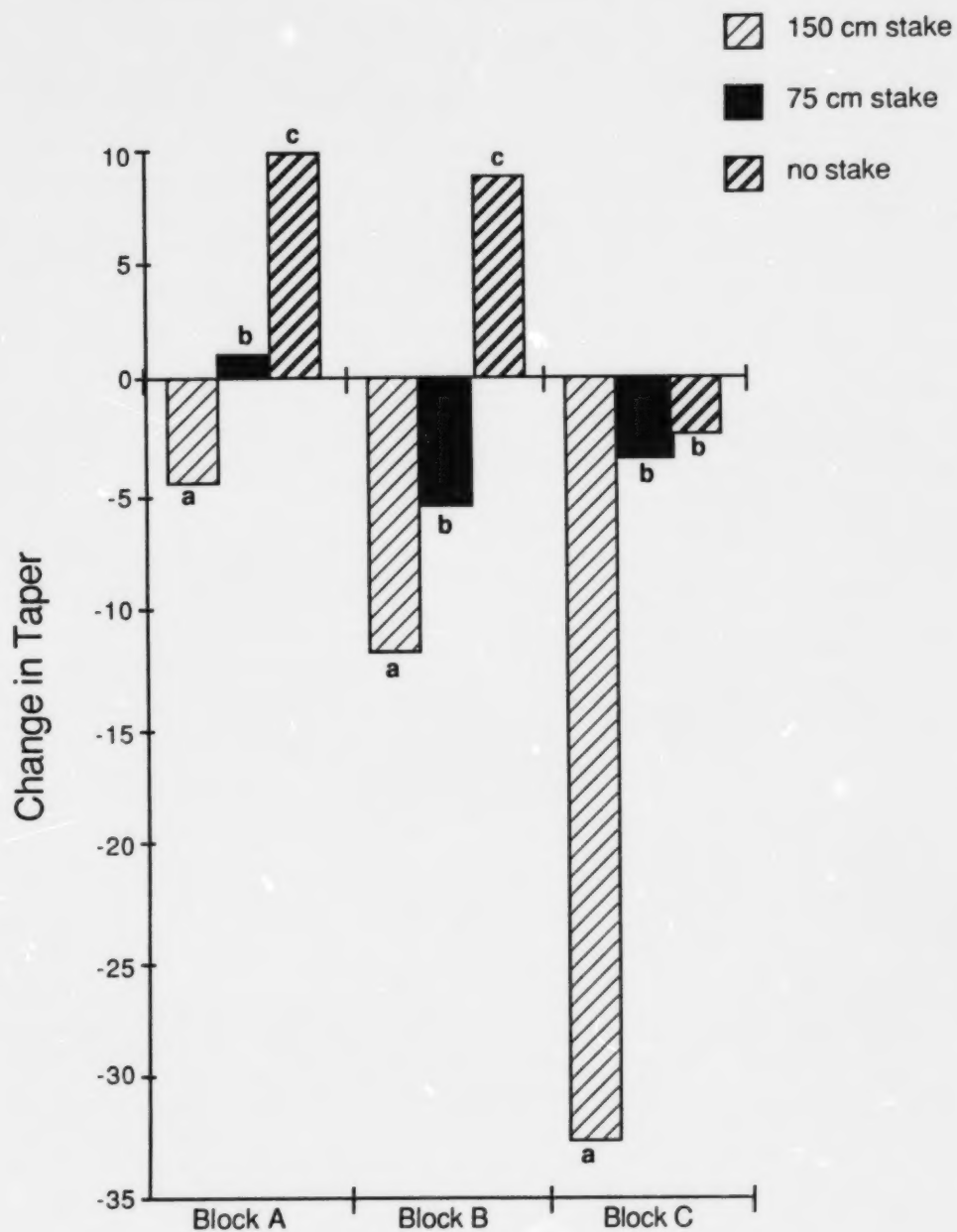


Figure 14/ Change in taper of ash tree trunks as influenced by the staking treatment. Within each block observation bars with different letters above are significantly different at the 5% level using the LSD test.

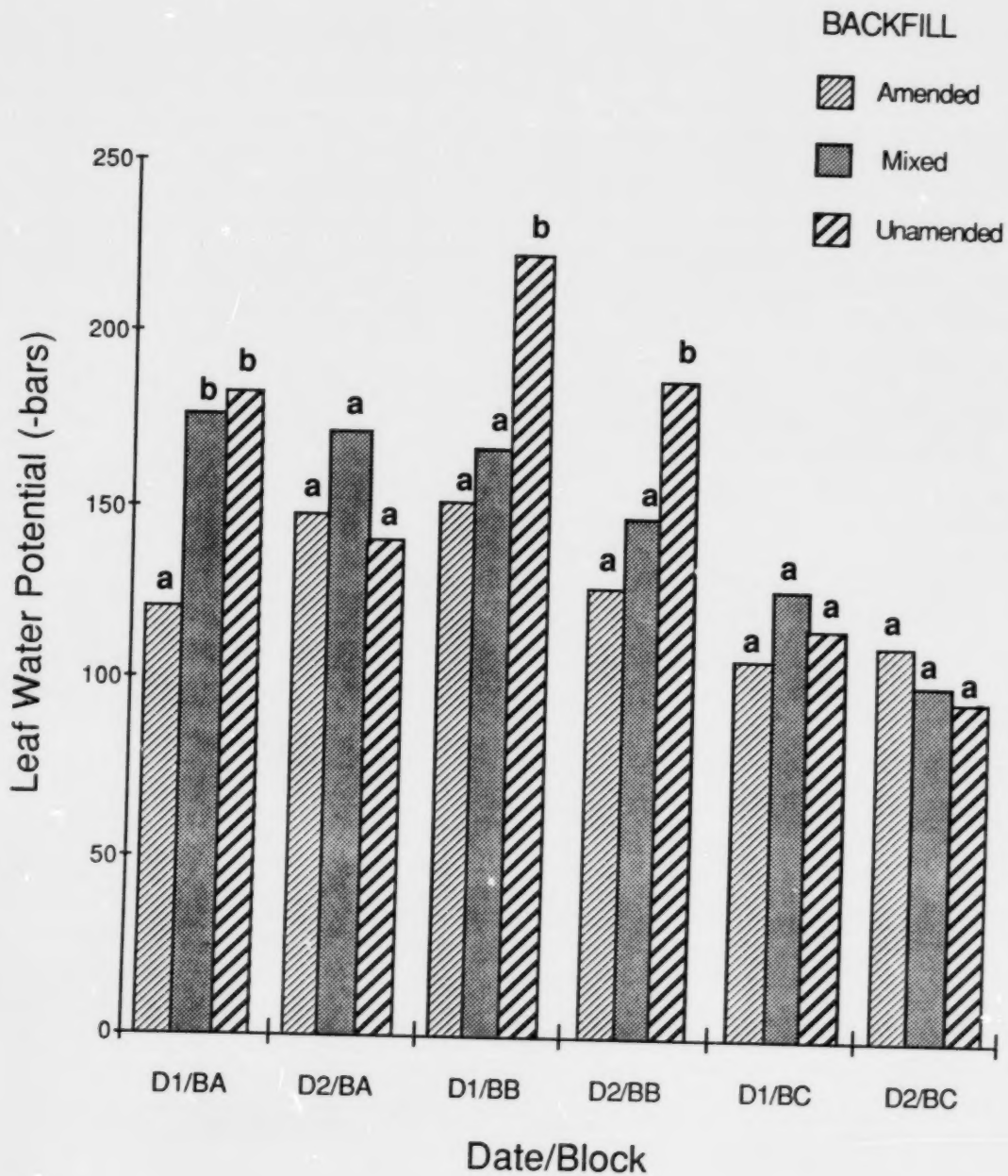


Figure 15/ Leaf water potential of ash trees by individual block at two different dates as influenced by backfill treatment. Within each date/block observation bars with different letters above are significantly different at the 5% level using the LSD test.

D1 = first measuring date (July 17, 23, and 24)

D2 = second measuring date (August 23, 24, and 27)

B = block

The apparent "recovery" of the trees in the clay unamended backfill in two of the blocks may have been related to the moisture conditions within the backfill. Precipitation was abnormally high in July and August. The availability of soil moisture, which may be affected by the type of soil used as backfill, may have been lower in early summer but after heavy rainfalls in July and August, the backfill would have less of an effect on moisture availability due to the saturated soil conditions. The tree would also become more established and have a greater ability to absorb sufficient moisture from the soil to satisfy transpiration demands.

b) Spruce

The backfill and mulch treatments did not appear to significantly influence the water potential of the spruce trees (Fig. 16). At both measuring dates, the trees planted in the amended soil had slightly more negative water potentials, but the difference was not great enough to indicate a true treatment effect.

The spruce trees were planted as balled and burlapped trees and thus have an undisturbed ball of soil and root. This ball would be similar in every tree and unless the surrounding soil affected the movement of soil water in and out of the ball, or the ball was damaged during planting, the availability of water to the trees should not be radically different. A difference in the water availability, as a result of the different backfill treatments, may not occur until root growth begins to exploit the soil area outside of the original root ball.

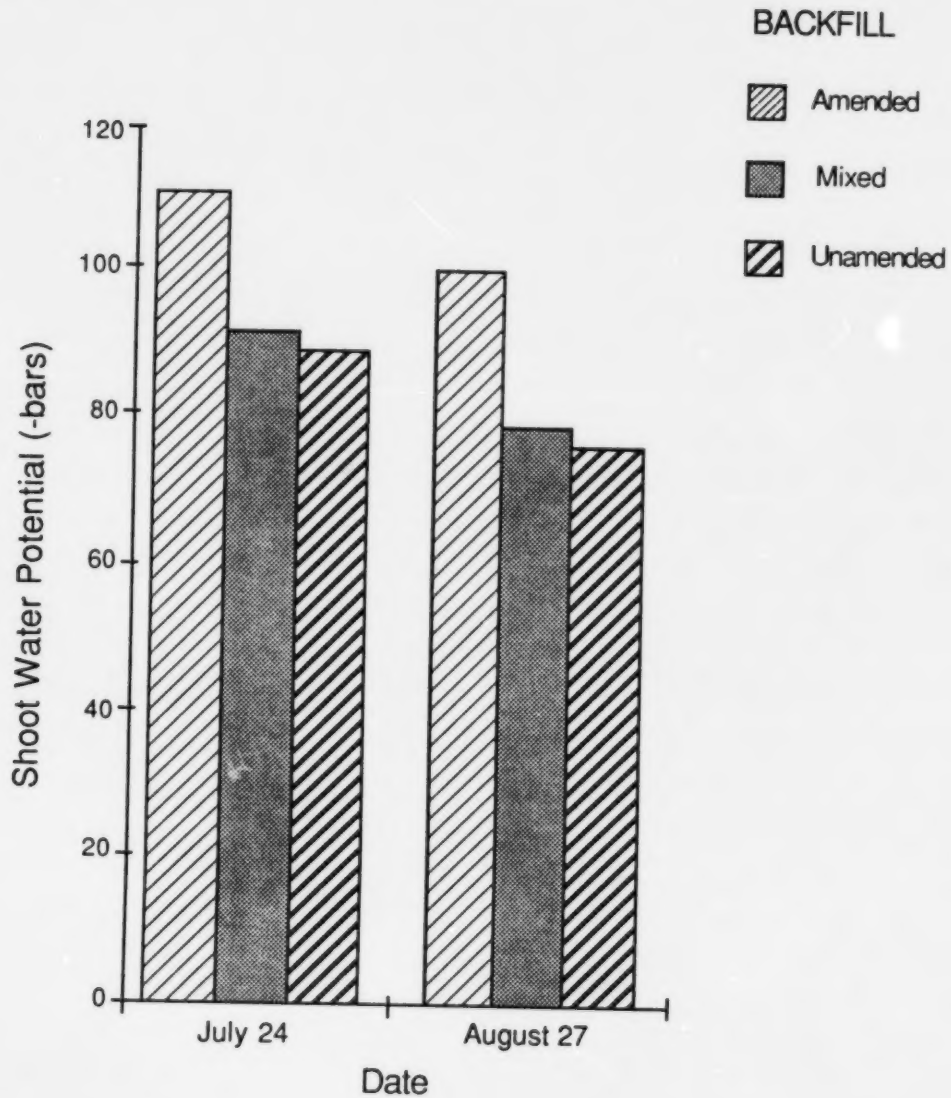


Figure 16/ Shoot water potential of spruce trees at two dates as influenced by backfill treatment. There were no significant differences.

3.1.5/ Canopy Density

a) Ash

Canopy density of the ash trees was visually assessed prior to fall defoliation. Trees planted in the amended backfill had a significantly higher rating than either the mixed or unamended backfill treatments (Fig. 17). The density of a tree's canopy is a function of both shoot elongation and leaf development. Trees planted in the amended backfill had a greater quantity of bud development than the other treatments (Fig. 6). As illustrated by the water potential values recorded in July (Fig. 15), moisture conditions were more favourable during this critical period of shoot development and leaf expansion in trees planted in the amended backfill. These conditions would have contributed to the formation of a larger canopy on trees planted in the amended backfill.

b) Spruce

The spruce were visually assessed in August. The assessment was based on the general condition and vigour of the tree. Spruce trees planted in the amended soil had a slightly higher rating although it was not significantly different from the other two treatments (Fig. 18).

Again, this may be related to the somewhat more favourable moisture conditions in the amended backfill surrounding the original root ball. The root ball provides a buffer for the spruce trees against unfavourable soil conditions and probably suppresses any treatment response until root growth occurs outside of the soil ball in significant quantities.

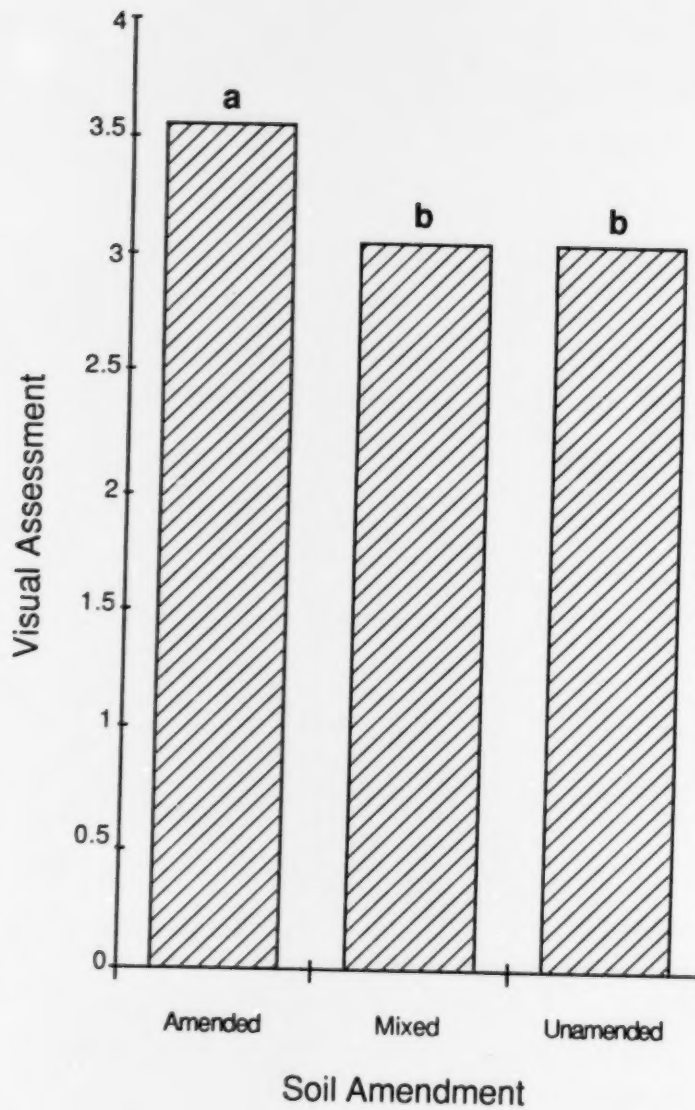


Figure 17/ Visual assessment of the canopy density of ash trees for each backfill treatment. Scored on a scale of 0 to 5 (0 = dead, 5 = best). Bars with different letters above are significantly different at the 5% level using the LSD test.

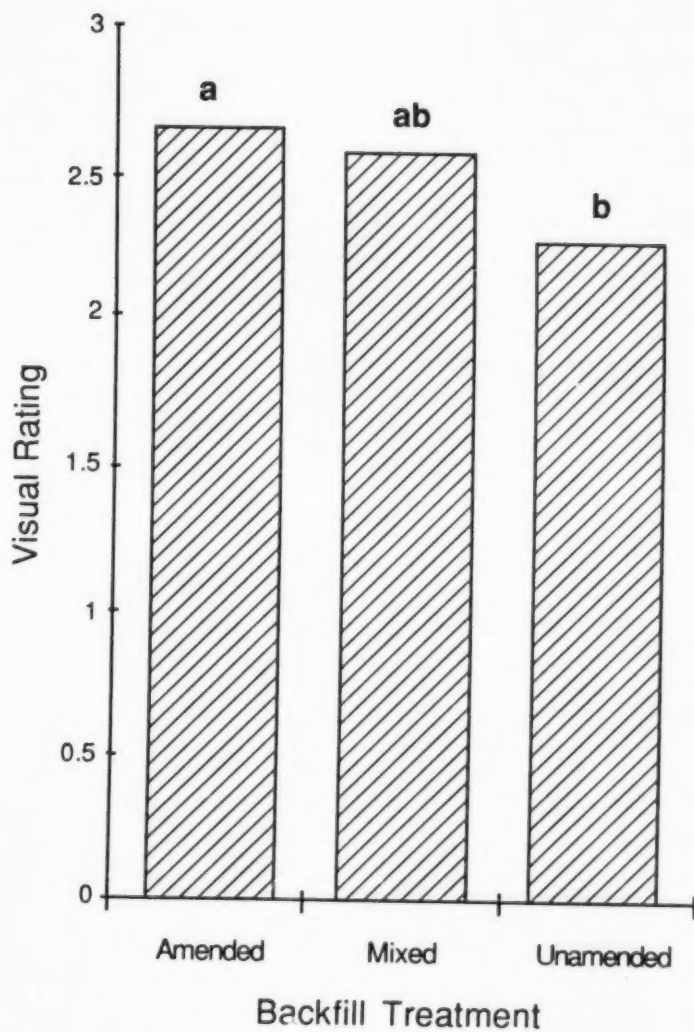


Figure 18/ Visual assessment of spruce growth and vigour for each backfill treatment. Rated on a scale of 0 to 5 (0 = dead, 5 = best). Bars with different letters above are significantly different at the 5% level using the LSD test.

3.1.6/ Defoliate Date

The date of complete defoliation was recorded for each ash tree (Fig. 19). Initially there was no indication of an effect of any of the treatments on the time of defoliation. However, by October 10, there were significantly more defoliated trees in the amended backfill treatment group than either of the other two backfill treatments. A series of frosts in mid-October quickly defoliated trees in all of the treatments.

Precipitation was abnormally high during mid- to late-summer and fall of 1985 (Figs. 22 and 23). During this period, the planting holes were inundated with water. One of the symptoms of anaerobic soil conditions is premature leaf senescence and defoliation (Russell, 1977). A possible explanation for a more rapid rate of defoliation of the trees planted in the amended backfill may be related to soil permeability. Standing water was observed on the surface of the clay backfill, indicating slower penetration of water into the smaller soil pores of the clay. The amended backfill, which was very sandy and porous, would become saturated with water more rapidly. Thus oxygen in the soil could be depleted more rapidly in the amended backfill, causing anaerobic conditions and the premature leaf fall observed.

3.2/ Physical Measurements

3.1/ Soil Analysis

Several parameters were determined for the native clay and topsoil as well as the imported soil mix used as the amended backfill treatment (Fig. 20 and 21). The imported soil differed greatly in several aspects as compared to the native clay and the native topsoil, which were somewhat similar in many respects.

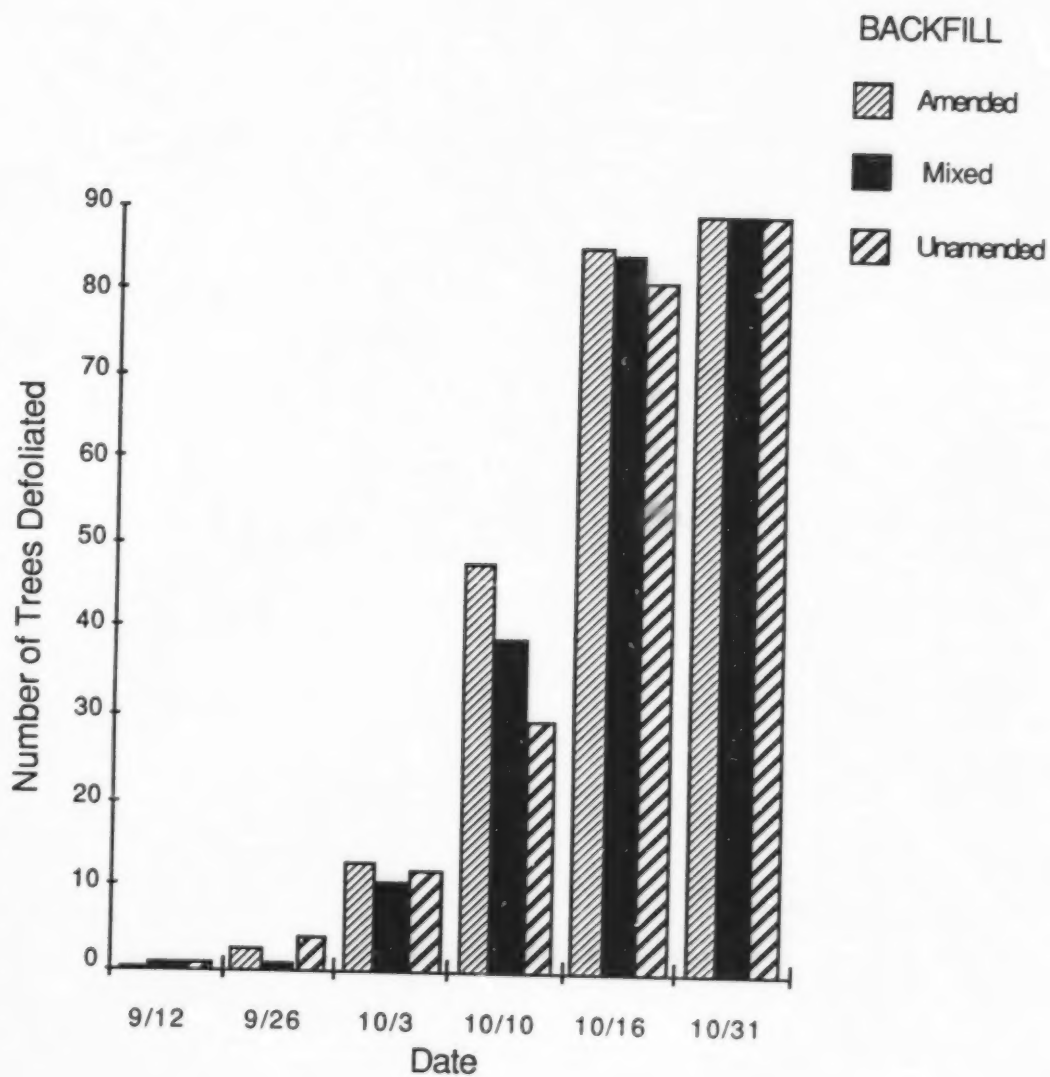


Figure 19/ Defoliation dates of ash trees as influenced by backfill treatment.

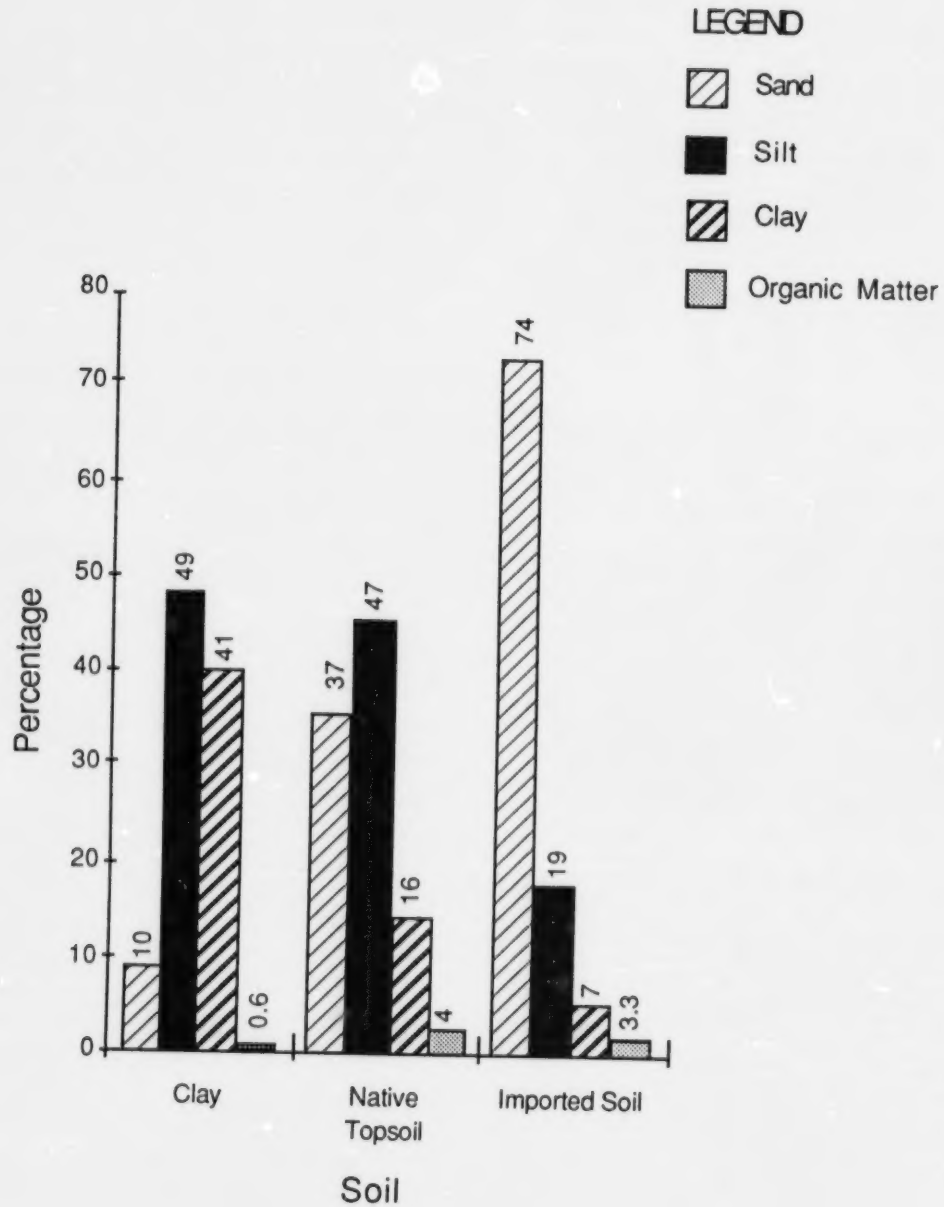


Figure 20/ Results of soil analysis of native clay, native topsoil and imported soil mix.

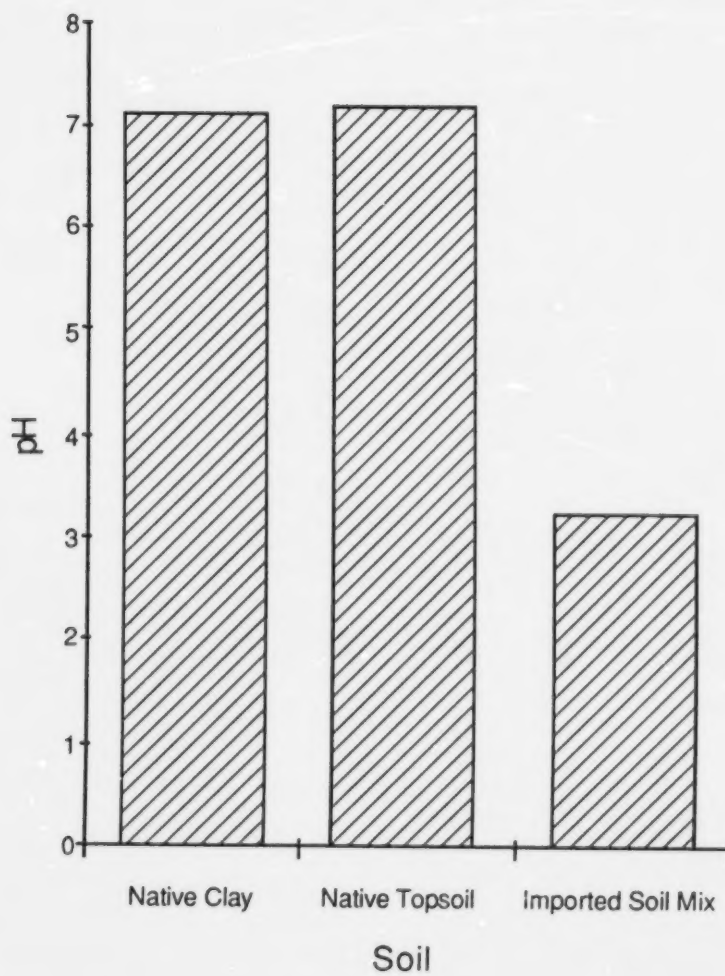


Figure 21/ Soil pH of native clay, native topsoil, and imported soil mix.

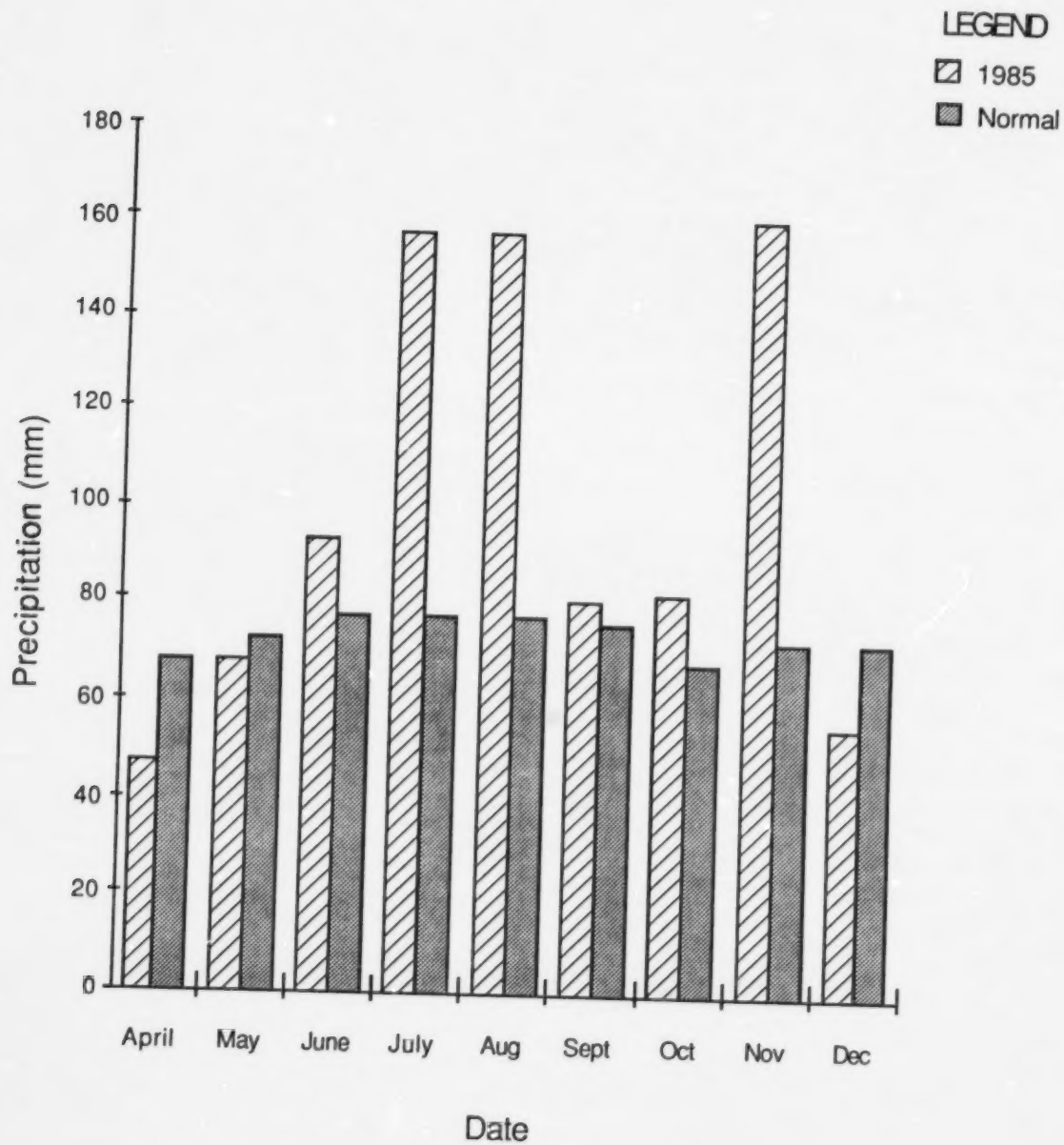


Figure 22/ Monthly precipitation summary for April to December, 1985.

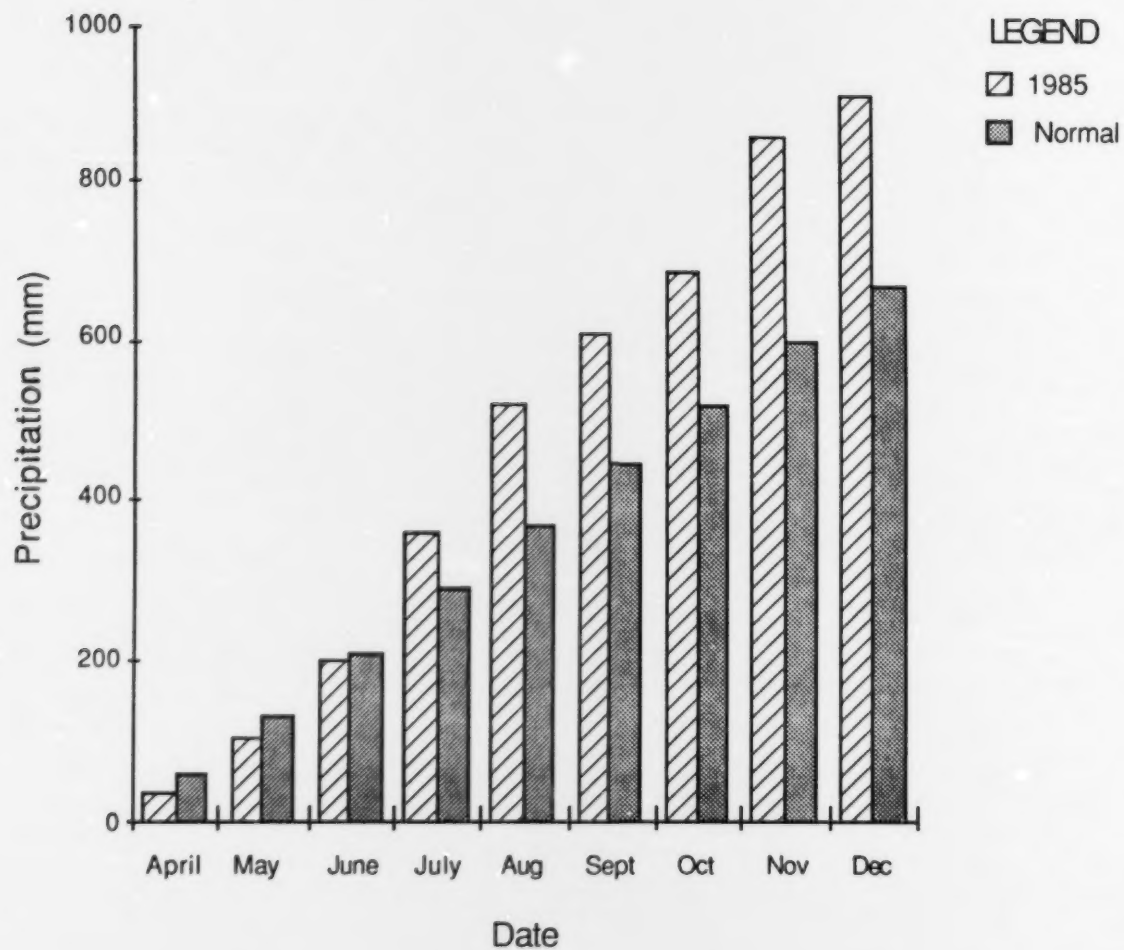


Figure 23/ Cumulative precipitation summary for April to December, 1985.

The imported soil mix had a much higher sand content and a lower pH as compared to the native clay and topsoil. The native clay had a much lower organic matter content as compared to the other two soils tested. The imported soil mix was classified as a sandy loam. The native clay and topsoil were classified as silty clay and loam soils, respectively.

The imported soil would contain larger size pores than the clay backfill. The presence of a greater quantity of organic matter would also contribute to the structure of the imported soil mix. These factors would make the imported soil mix more conducive to root growth -- although in a dry year, the high sand content may contribute to reduced water holding capacity in this soil.

The presence of the heavy clay soil around the perimeter of the planting holes could limit root growth into the surrounding soil. The clay backfill would not be as optimal for root growth as the imported soil, but the similarity between it and the surrounding soil could improve tree establishment in the long term by reducing the physical barrier to root growth out of the planting soil into the surrounding soil. This barrier is thought to be present at the interface of two radically different soils (Whitcomb, 1979). The presence of a thick topsoil layer on this site may reduce this effect since root growth is normally confined to the top 10 to 20 cm layer of soil (Watson and Himelick, 1982). The native topsoil would be a better medium for root growth than the clay because of its higher organic matter content and more even distribution of sand, silt, and clay particles as compared to the native clay.

The backfill treatment that consisted of a 50/50 mix of the imported soil and the native clay would probably fall between the two component soils in terms of sand, silt, clay, and organic matter content. The actual structure of this soil may differ from the other two soils as a result of the mixing of the fine particles of the native clay with the coarse particles of the imported soil. When a fine soil is mixed with a coarse soil, total bulk volume and porosity of the soil decrease as a result of the packing of the fine soil particles into the larger pores of the sandy soil (Spomer, 1979).

The preceding discussion of root growth in response to the three backfill treatments is purely speculative. Actual response of the trees to the backfill treatments, in terms of root growth, will not be revealed until excavation of the site in 1989.

3.2.2/ Weather Data

Precipitation summaries were acquired from the Environment Canada Weather Office at the Waterloo-Wellington Airport (Figs. 22 and 23). July, August, and November were months of abnormally high precipitation. April rainfall was slightly below normal.

Temperatures were measured at different levels in the soil for both the ash and spruce experiments (Figs. 24 and 25). A similar pattern was observed in both groups of trees. Surface temperature was very high in the woodchip mulch treatment. This would be due both to the heating of the woodchips and heat reflectance from the woodchips. At a depth of 15 cm, the soil temperature was lowest under the woodchip mulch. The mulch acts as an insulating layer and reduces solar heating of the soil.

Surface temperature was higher in the herbicide treatment than in the grassed-over treatment. This is a result of the shading of the soil surface by the grasses and weeds that invaded the untreated soil surface after planting. As a result, the temperature at a depth of 15 cm was also slightly higher for the herbicide treatment.

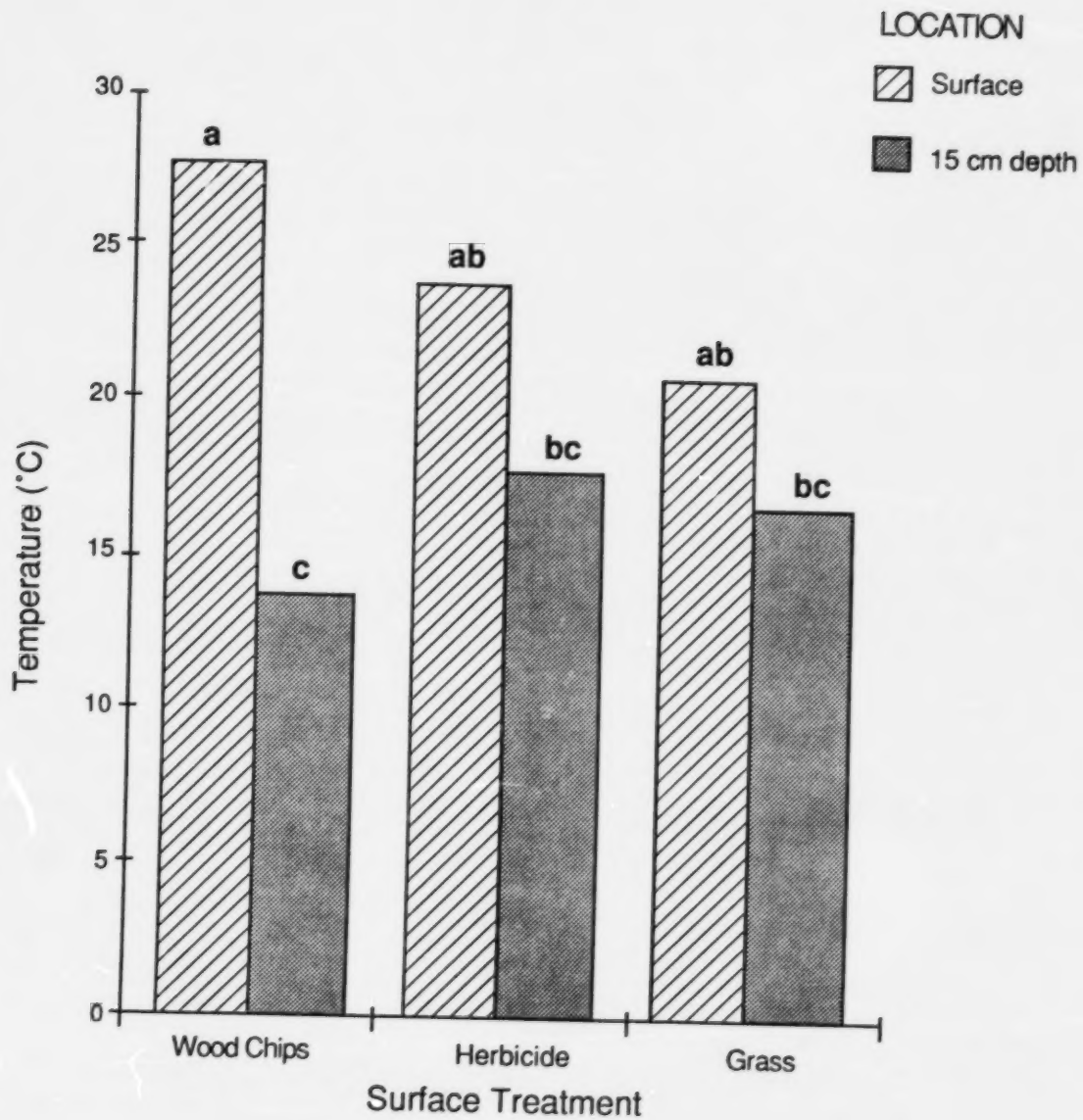


Figure 24/ Temperatures at the surface and at a depth of 15 cm for three surface treatments on ash. Bars with different letters above are significantly different at the 5% level using the LSD test.

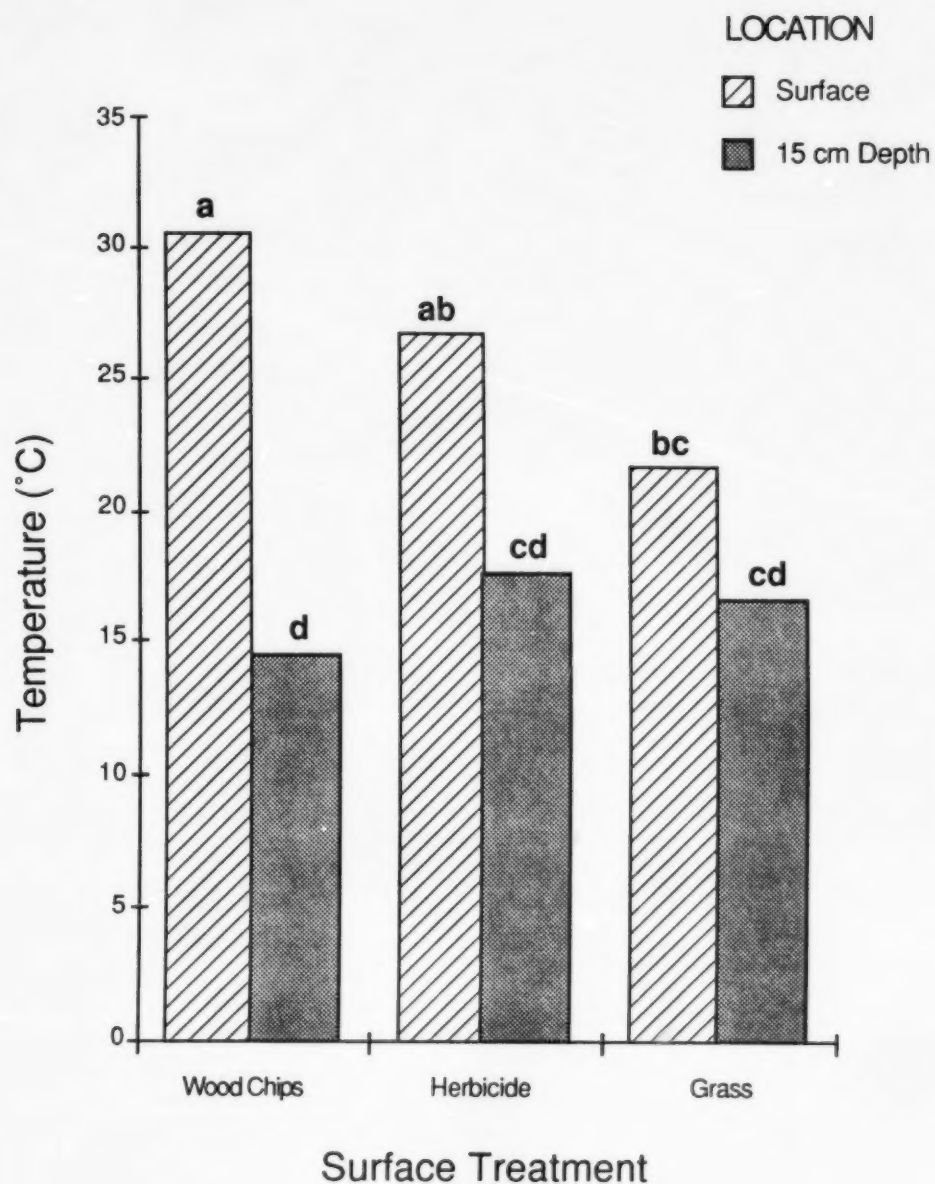


Figure 25/ Temperatures at the surface and at a 15 cm depth for three surface treatments on spruce trees. Bars with different letters above are significantly different at the 5% level using the LSD test.

3.2.3/ Container Experiment

a) Ash

Ash trees planted in the amended soil had a greater quantity of both new root growth and new shoot growth (Fig. 26, 27, and 28). In a container situation, the amended soil has many more desirable characteristics when compared to the clay. It is much more readily penetrated by water and drains more freely. It also has greater aeration than the clay soil. Care should be taken not to extrapolate these results directly to the field experiment. The containers used were free draining as opposed to the poor drainage conditions in the field.

b) Spruce

The results of the spruce container experiment illustrate the buffering effects of the soil ball (Fig. 29). Most of the root growth in both treatments was confined to the original soil ball. There was very little exploration of the surrounding soil by new root growth, especially in the clay soil treatment. No significant difference was found in growth between the two soil treatments. The shoot growth of the trees grown in the amended soil was slightly higher than the clay soil treatment, but was not statistically different. A second harvest of these plants (fall, 1986), after two growing seasons, should give a better indication of the extent of exploration of the backfill soil by new root growth.

3.3/ General Observations

Transplant survival was excellent in the ash trees. All of the trees grew to some degree over the 1985 season. The effect of the saturated soil conditions that caused premature defoliation of many ash trees will not be evident until budbreak in the spring of 1986. Six spruce trees succumbed to the transplant process. This is equivalent to a 96% survival rate. Of the trees that failed to grow, three were planted in the unamended backfill, two in the amended backfill, and one in the mixed backfill.

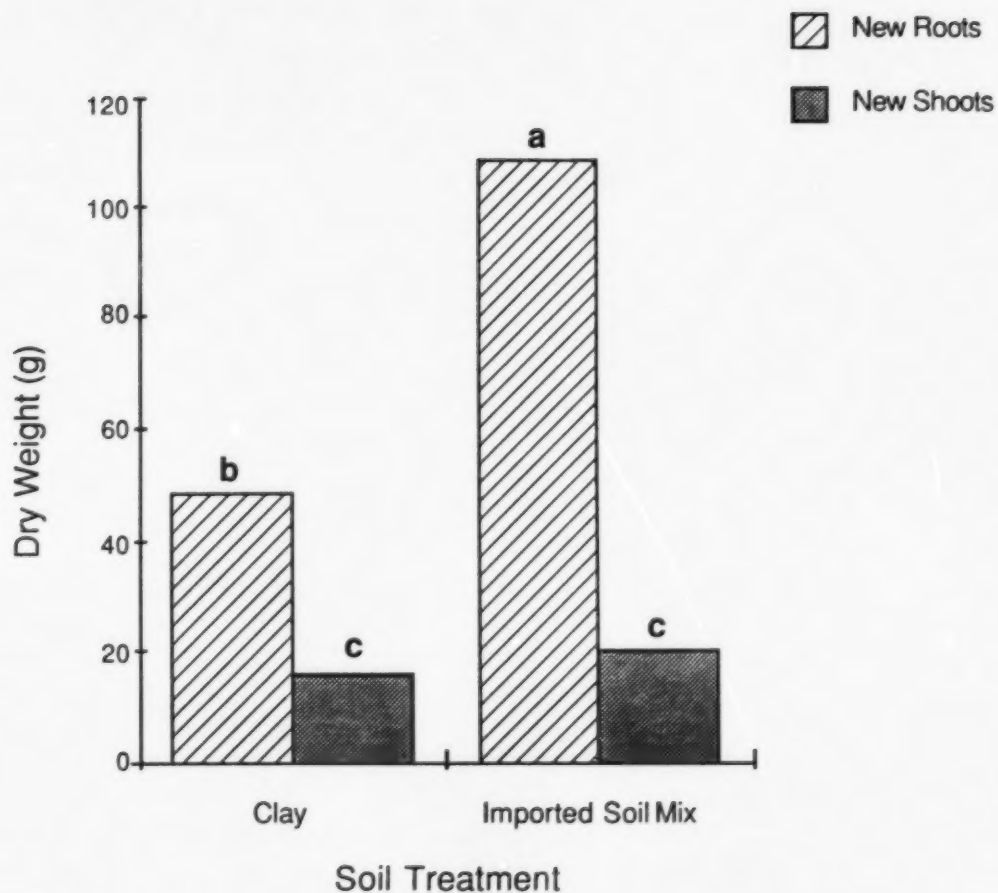


Figure 26/ New root and shoot growth of ash trees planted in clay and imported soil mix (amended backfill treatment) in containers. Bars with different letters above are significantly different at the 5% level using the LSD test.

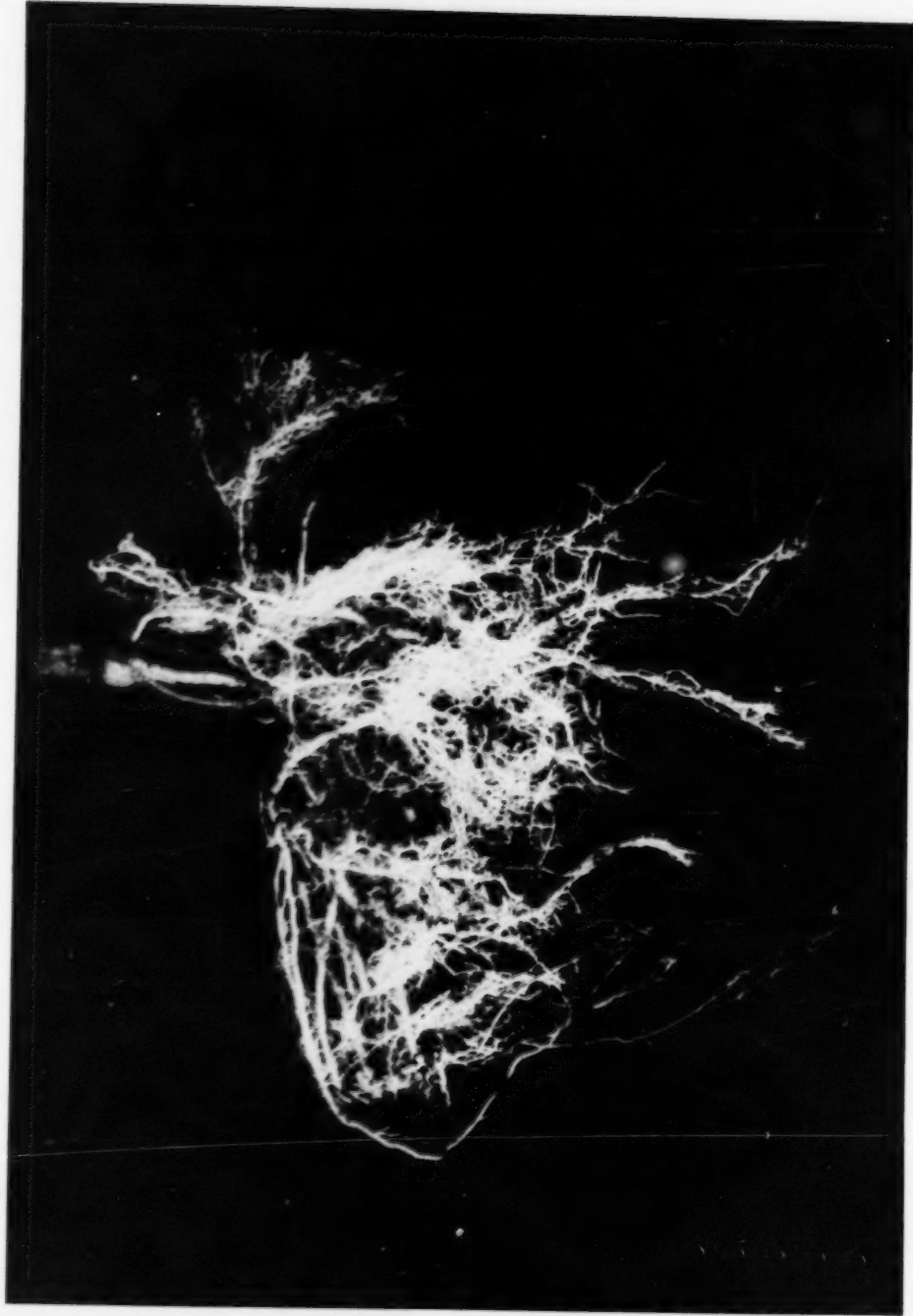


Figure 27/ Root system of ash tree grown in native clay soil in a container.

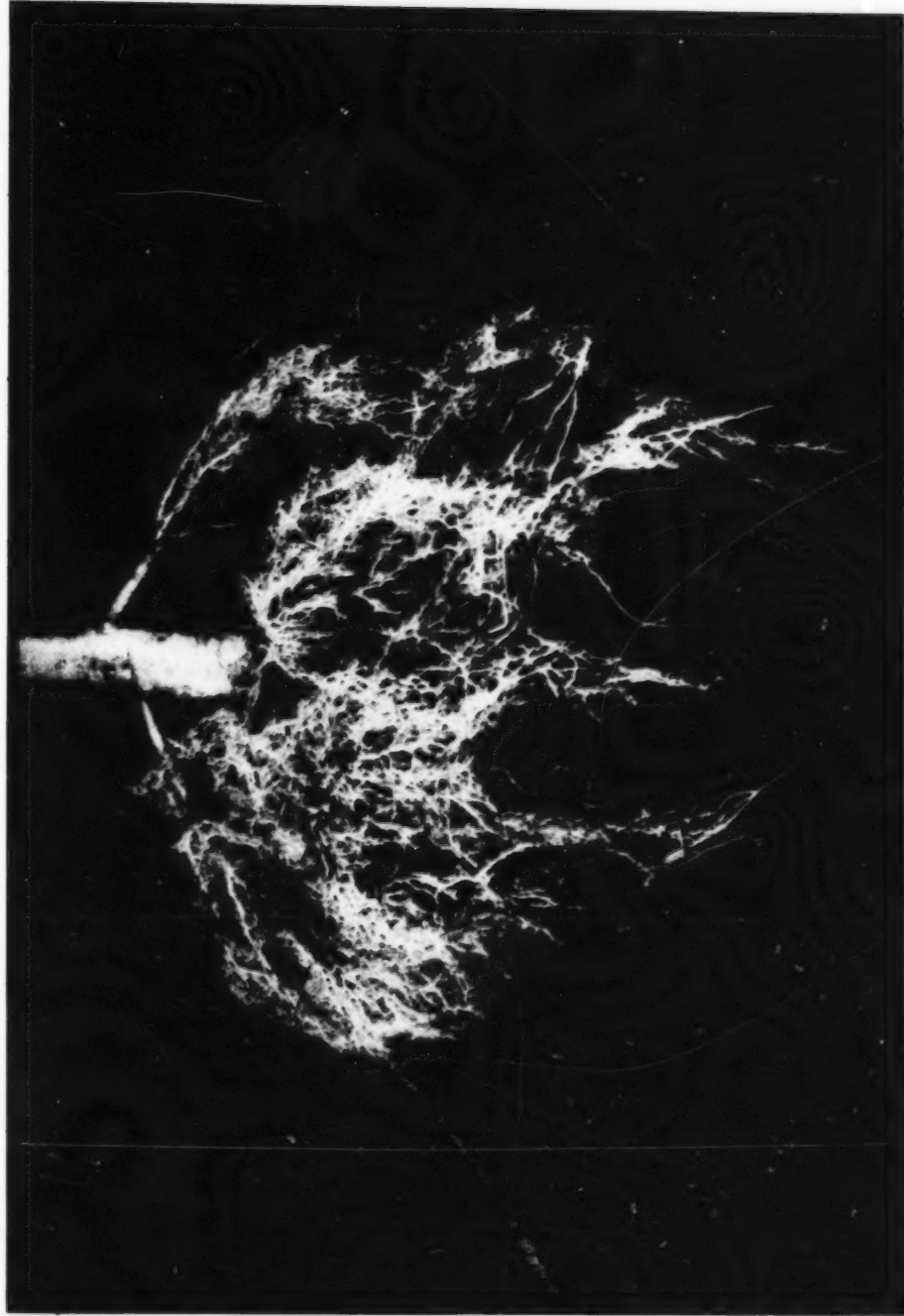


Figure 28/ Root system of ash tree grown in imported soil mix
(amended backfill treatment) in a container.

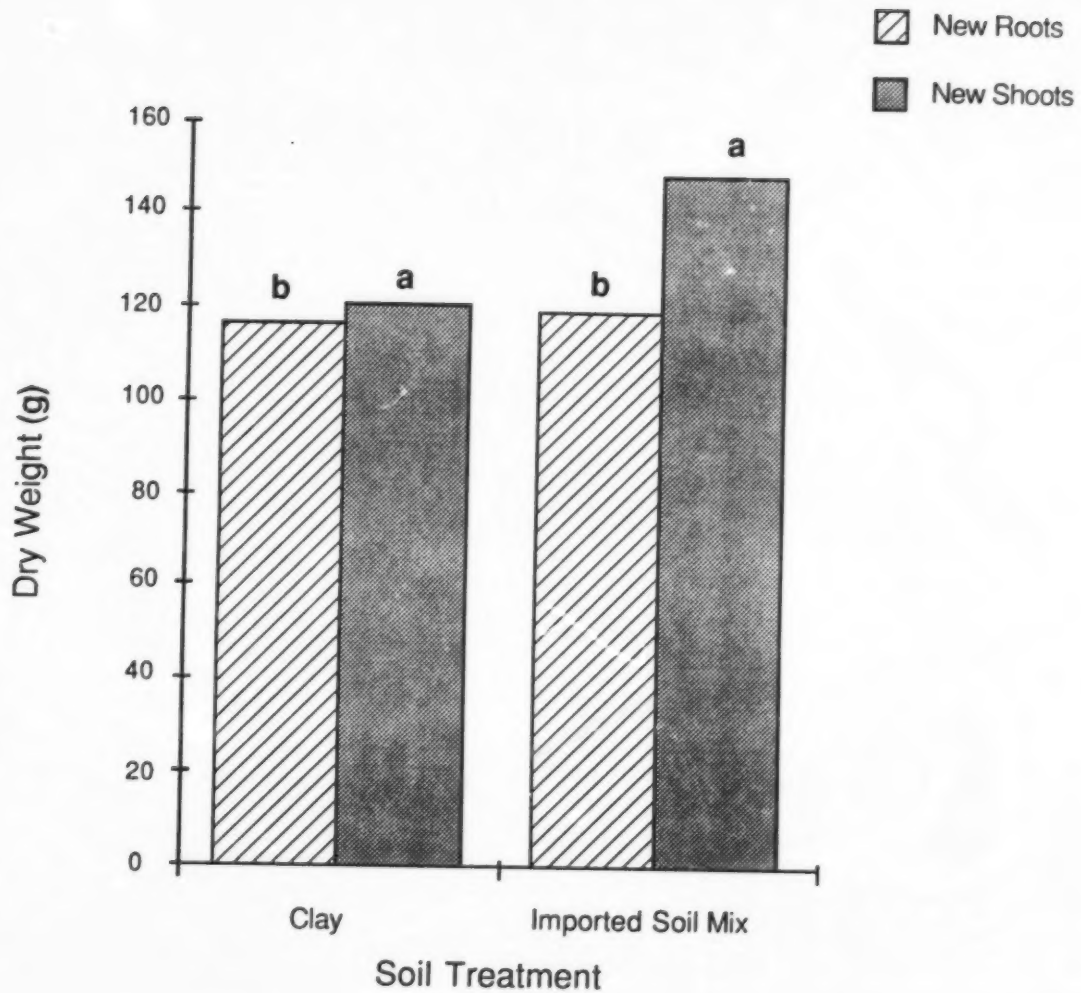


Figure 29/ New root and shoot growth of spruce trees planted in native clay and imported soil mix (amended backfill treatment) in containers. Bars with different letters above are significantly different at the 5% level using the LSD test.

There were no serious pest problems in either species. Numerous tomato hornworms attacked the foliage of the ash trees, but they were removed by hand before any significant amount of damage was done. Many of the ash trees had marginal leaf necrosis, a browning of the leaf margin, late in the season. It appeared to be related to the anaerobic soil conditions that were evident on the site. The heavy rains in July and August inundated the planting holes with water, and drainage from the holes appeared to be slow.

In general, growth appeared to be normal for recently transplanted trees of both species.

4/ GENERAL CONCLUSIONS AND SUMMARY

There were several interesting results from the first year of this five-year study. Definite conclusions cannot be drawn until the end of the study when data from root system excavations can be evaluated along with data of top growth. At this time, we only have an "above-ground" idea of the effects of the various treatments.

Shoot elongation was greater in the ash trees planted in the mixed soil backfill treatment. The differences between the amended and unamended treatments were not significant. Overall height growth was greatest in the amended backfill treatment group. Water stress, as measured by leaf water potential, was initially lower in the trees planted in the amended backfill. Only within one block of ash trees was the water stress significantly lower in the amended backfill at a later measuring date. By mid- to late-summer, there was no difference among the backfill treatments in the various parameters measured, except for height growth. Most of this growth occurred early in the season when the backfill treatment had a significant effect on the water relations of the trees.

The abnormally high levels of precipitation during 1985 may have influenced the results by negating the effect of the backfill on the availability of soil moisture. The heavy rains prevented soil water from becoming a limiting factor, influenced by the water retention characteristics of the three backfill soils. A tensiometer was acquired late in the season to perform soil moisture readings, but by that time the site was so saturated with water that soil suction, an indicator of moisture content, was nil. In addition, the holes were visibly wet and water was observed on the surface of several holes. An attempt to measure soil permeability, a measure of the rate of water movement through the soil, was foiled by the high soil moisture content. The clay was so saturated with water that permeability was too slow to be measured. Planting holes were inundated with water, causing the anaerobic conditions that resulted in the early defoliation of the ash trees.

The pruning treatments stimulated both lateral and height growth, an observation not different from the observations of others (Castle, 1983;

Kelly and Moser, 1983). Pruning also reduced the development of trunk taper, an observation also consistent with the literature (Harris, 1984; Leiser et al, 1972). The effect of pruning on root development will not be known until excavation.

The mulch/weed control treatments had no noticeable effect on tree growth but influenced soil temperatures. The mulch treatments were applied mid-season, and the somewhat cool summer, heavy precipitation, and initial lack of weed growth in the untreated holes reduced possible effects of the treatments. A response may be noticed in subsequent years.

The staking treatments had a significant effect on the development of trunk taper. Taper was reduced both by the presence of a stake, and within the staked trees by the height of attachment. A higher point of attachment resulted in less taper development. These results agree with a theoretical analysis of staking height (Leiser and Kemper, 1968) and other staking experiments (Harris, 1984; Harris and Hamilton, 1969; Leiser et al, 1972; Wrigley and Smith, 1978). Close examination of taper development revealed a gradation across the experimental plots that may indicate the importance of wind sway in trunk development.

In general, the first year of this study was successful in revealing early trends in tree responses to the various treatments. Again, it must be stressed that root growth could not be studied in the field experiment without disturbing the trees. Root growth is the most critical factor in the establishment of trees on a new site after transplanting as roots represent the interface between the tree and its new soil environment. The extent of root development in the disturbed soil zone, as well as into the surrounding native soil, will dictate the long-term survival of the tree.

Although this past season was characterized by heavy summer rains, their occurrence will contribute to the value of this experiment if the trees are exposed to a variety of different environmental extremes over the five-year period. Under extreme environmental conditions, site characteristics and tree responses should be clearly exhibited.

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